CANADIAN JOURNAL
OF PLANT SCIENCE

VOLUME 38 JULY 1958 No. 3

THE INHERITANCE OF FLUORESCENCE IN CLINTON OATS[1]

J. W. MORRISON[2]

Canada Department of Agriculture, Ottawa, Ontario

[Received for publication August 14, 1957]

ABSTRACT

Under an ultra-violet lamp, fluorescent off-type seeds were picked from a registered sample of non-fluorescent Clinton oats. Crosses were made between the two types of seeds and the F_2 segregated into a 3:1 ratio of fluorescent to non-fluorescent types. Parental lines were grown for three generations under different environments. The environment did not change the reaction but did affect the density or colour of fluorescence exhibited. In some parental lines, off-types appeared. They were presumed to be mutations. Some information about the origin of the genes for non-fluorescence is also presented.

INTRODUCTION

The seed of oat varieties is usually classed as being "yellow" or "white" by the natural colour of the hulls. Off-shades in colour present a problem in identification and the ultra-violet light has been used to discriminate between the types because, under this light, normal seeds of white varieties appear greenish-blue or "fluorescent" and seeds of varieties with a yellow colour appear reddish-purple and are "non-fluorescent". Typical seed of the variety Clinton has a yellow coloured hull and is "non-fluorescent" under the ultra-violet light. Off-types that are "fluorescent" occur in this variety. These seeds may be various shades of colour from white through cream and tan to a light brown and it is difficult to distinguish them from typically yellow seeds, particularly in weathered samples, without the aid of an ultra-violet light. A study of the origin and inheritance of off-type fluorescent seeds was made because of the concern shown by seed inspectors, seed growers and plant breeders and because reports indicated that, under some environments, the fluorescence was sufficiently modified that identification was not positive. Because of the variability in seed colour in Clinton lines, seeds of other yellow hulled varieties and yellow or brown coloured species were also examined to study the interaction of yellow colour and non-fluorescence.

MATERIALS AND METHODS

For this study two models of ultra-violet lamps were used; both were long wave (3660 Angstroms) lamps. The following abbreviations are used in the text: F = *fluorescent*; NF = *non-fluorescent*; IF = *intermediate fluorescent*; UV = *ultra-violet.*

[1] Contribution No. 221 from the Cereal Crops Division, Experimental Farms Service, Canada Department of Agriculture

[2] Cytogeneticist, Cereal Crops Division, Central Experimental Farm, Ottawa, Ont.

Oat varieties are classified as being F or NF by the reaction of the outer coat of the lemma and palea (hulls) under the UV light. These tissues are maternal tissues and any change in reaction resulting from hybridization does not appear until the next generation. Thus F_1 seeds naturally have the fluorescent characteristic of the maternal parent; F_2 seeds on the F_1 plants are uniform; and segregation does not appear until F_3 seeds are formed on the F_2 plants.

Random samples of registered Clinton seed from eight growers in Ontario were found to contain 25-75 F seeds per half-pound. From one sample six typical seeds from each of the F and NF classes were planted in individual pots in the greenhouse for crossing, chromosome counts, and colour observation. The chromosome counts were made on root tips of each type. Panicles were also fixed for a study of meiosis. Crosses were made between plants arising from F and NF seeds. The plants were harvested separately, and panicles were threshed by hand to prevent mixing. Seeds of each plant were examined under the UV lamp. F_1 seeds were sown in individual pots in the growth chamber with four NF and three F checks. These checks were used for additional crosses. All seeds were harvested as before and examined under the UV light.

The F_1 and F_2 seeds obtained in the greenhouse and growth chamber were space planted in the field in the spring of 1956 along with 24 seeds from each of nine F and nine NF lines. All plants were threshed individually with a head-row thresher and then the seeds of these plants were examined under the UV light and placed into one of three categories: F, IF, and NF.

EXPERIMENTAL RESULTS

General

Other parts of the oat plants were examined under the UV light to see if there were differences between F and NF lines of Clinton. The roots, the inside of mature stems and the inner side of the lemma and palea fluoresced equally in both lines.

Some comments are necessary about the appearance of the samples under the UV light. The IF seeds fluoresced but with a dusky violet colour. It was quite typical for the group. Most of the field material was weathered and the seeds had a darker tone. Some difficulties in classification were encountered between IF and F classes but the NF seeds were so characteristically dark that they could be classified with certainty.

Any classification into categories of colour under normal daylight is inconclusive when colour differences are small and variations within a sample are nearly as great as variations between samples. There were noticeable differences in intensity of yellow within the NF samples of Clinton. The IF seeds were also variable in colour. Most were intermediate in colour between the colours of the two parents used in the cross. It was thus only possible to classify F_2 samples by comparing them with parental colours because some intermediates were more yellow than NF lines.

TABLE 1.—REACTION UNDER THE ULTRA-VIOLET LIGHT OF SUCCESSIVE GENERATIONS OF PARENTAL LINES OF CLINTON

Original seed	1st generation seeds	2nd generation plants[1]		
		F	IF	NF
Yellow-1	17 NF			14
2	42 NF			19
3	36 NF	1	1	16
4	46 NF		1	19
5	54 NF		1	20
6	75 NF			20
7	140 NF			22
8	68 NF			24
9	100 NF			23
10	84 NF			24
White-1	48 F	24		
2	44 F	21	2	
3	95 IF		21	
4	58 F	24		
5	101 F	24		
6	68 F	24		
7	136 F	24[2]		
8	46 F	20		
9	124 F	24		

[1] Except in yellow-1, 24 seeds were space planted; some did not germinate Fluorescent ratings were made on 200-300 seeds from each plant.
[2] Two NF seeds were found in one plant.

Reaction of Parental Lines and Hybrids

The reaction under the UV light of parental lines is given in Table 1. Segregation occurred in one line in the first generation and in four lines in the second. The segregation occurred on a plant basis. However, in one exceptional case, one spikelet with two NF seeds was found among seed of a F plant. Because irregularities at meiosis were observed a further generation of the plant, yellow-1, was grown but all seeds were again NF.

The 59 F_1 seeds of crosses between NF and F types were similar to the female parent in reaction under the UV light. The F_2 seeds on the F_1 plants were all IF. The F_3 seeds of 15 of these crosses were classified as shown in Table 2.

Cytological Examination

There were 42 chromosomes in the root tips of all plants examined. No abnormalities such as fragment chromosomes or telocentrics were present [cf. Morey (7)]. Meiosis was normal and regular in all hybrids and parental lines with one exception. A detailed examination of plant yellow-1 revealed some interesting cytological data on bridge formation and chromosome breakage in one chromosome. This irregularity was not associated with a change in reaction under the UV light and no obvious segregation occurred in three generations of this material.

TABLE 2.—SEGREGATION IN THE F_3 PLANTS FROM CROSSES BETWEEN NF AND F CLINTON PLANTS

Hybrid	F	IF	NF	Total	X^2 3:1[1] 5% 3.84	X^2 1:2:1 5% 5.99
1 (Y × W)	22	46	25	93	0.17	0.20
2 (Y × W)	23	43	21	87	0.03	0.10
3 (Y × W)	16	39	26	81	2.17	2.58
4 (Y × W)	21	43	29	93	1.89	1.89
5 (Y × W)	21	45	24	90	0.13	0.20
6 (Y × W)	24	43	26	93	0.43	0.61
7 (Y × W)	18	30	13	61	0.44	0.83
8 (Y × W)	27	37	21	85	0.00	2.20
9 (Y × W)	31	42	22	95	0.17	2.98
10 (Y × W)	11	61	14	86	3.49	15.27
11 (Y × W)	4	57	23	84	0.25	19.30
12 (Y × W)	66	0	23	89	0.03	
13 (W × Y)	28	43	22	93	0.09	1.30
14 (W × Y)	27	47	20	94	0.69	1.04
15 (W × Y)	48	48	31	96	2.72	4.08
Totals	356	624	340	1320	0.40	

[1] F and IF classes grouped together as F

Reaction of Other Varieties and Species

One hundred and forty varieties of oats introduced in 1951 were examined under the UV light. Nineteen of them were NF and in these the seeds were yellow or some shade of yellow. Some of the selections had been sent as *A. sativa* var. aurea; in others, such as Gelbhafer, the varietal name indicated that colour had played a part in the selection. All of the NF varieties examined originated in Europe. Seeds of the species *A. byzantina*, *A. fatua*, *A. sterilis* and hybrids *A. sativa* × *A. sterilis* all fluoresced whenever the seeds were light yellow, yellow tan or tan. Dark brown or black seeds of these species and dark striped seeds of *A. strigosa* did not fluoresce. Apparently the dark pigments obscured or masked the fluorescence because yellow coloured patches or lightly coloured seeds did fluoresce.

DISCUSSION

Schlehuber *et al.* (8) observed that in some years environmental factors altered the expression of the F character of Andrew oats. Finkner *et al.* (4) also attributed some variation in reaction to the environment. Some differences in reaction between seed lots grown in the field and those grown in the greenhouse were also noticeable in the Clinton material under study. The seed from the field-grown crop appeared darker under the UV light. The difference was only obvious in F material; NF lots varied very little. It is well known that some oats will fluoresce with a different colour than others. This experiment indicates that much of the variation is due to masking by the presence of pigments in the hull. Under

the conditions of the experiment the reaction under the UV light was not changed by environment and the UV light can be used to distinguish between NF and F seeds.

When the ratios of the F_2 progeny (F_3 seeds) of the crosses between F and NF Clinton lines were calculated a satisfactory fit to a 3:1 ratio was established for all lines. It seems most probable, therefore, that the NF character is inherited as a simple recessive. Our results agree with those of Finkner *et al.* (4).

The material was also classified into an IF group and it is apparent from Table 2 that the segregation ratios of 1:2:1 were maintained in many of the lines. A variation in the intensity of fluorescence in the IF class existed in some lines and in one line (No. 12) no intermediates were produced. Akerberg (1) also had a good fit to a 1:2:1 ratio. It should be emphasized again that the IF group was fluorescent. Therefore, segregation involves a factor which tends to obscure fluorescence or change it enough to make it noticeably different from the normal F reaction. This factor probably is one governing seed coat colour.

The relationship of colour and NF was clarified somewhat by the study of other species and varieties. All NF strains were yellow or some shade of yellow but not all yellow coloured strains were NF. Dark pigments in some of the species masked some of the fluorescence. This was expected because, according to De Ment (3), masking or quenching can be caused by concentration changes or by coloured substances. It is well known that pigments are greatly affected by environment. In oats, for example, early-harvested seed of *A. byzantina* may be yellow but later-harvested material will be dark brown. Here, then, is the reason why environment has an effect on the reaction to the UV light: it alters the intensity of the colour and this affects the fluorescence of the hulls.

Without data from an elaborate crossing experiment it is difficult to hypothesize on the inheritance of colour factors. Because there are light and dark yellow lines of NF Clinton and white and yellowish F lines it is reasonable to assume that hull colour in this variety is probably governed by several genes. It is also quite probable that this yellow colour which is associated with NF is a different colour from that of other species. Further information on the genetics of seed colour and the NF characteristic is available from the study of the varieties carrying the gene for NF. Most of the NF varieties listed by Finkner *et al.* (4) have one main oat variety in their background; that is the old German variety, Probsteier, or the old Milton (10). The NF varieties in the 1951 introductions came from Germany or Bulgaria and some can be traced directly to Probsteier. The NF yellow oats probably arose as a mutation in some Old Land race and were carried in mixtures until selections were made in Northern Europe.

Plants with fluorescent seeds appeared in three NF lines of Clinton (Table 1). How did these plants arise? The answer to this question is probably the answer as to why off-types occur in pure lines of Clinton. If natural crossing had occurred in the greenhouse a different type of segregation would have resulted. "Errors" of planting or harvesting

cannot be entirely eliminated, but every effort was made to prevent them. Environment does not cause such a change. The one remaining alternative is to consider that the change has been a mutation. The appearance of two NF seeds (actually a primary and a secondary) in the F seed from one plant must also be placed in this category but with some reservations. Mutations causing the related phenomenon of colour difference have been stressed by other workers. Akerman (2) gives the frequency for mutations in the black oats of Sweden as being as high as 0.5 to 0.7 per 1000; Gustafsson and MacKey (5) also quote 0.5 to 1.0. Because the mutation has been in both directions the fluorescent gene is unstable or mutable [cf. Sears (9) and McClintock (6)].

All seed stocks of registered Clinton had off-type F seeds. This experiment has shown that the difference between the two types is governed by one gene. There is also some evidence to show that the off-types arise as mutations. It is impractical to compute a mutation rate for this character from the limited data of this experiment. However, some consideration should be given to the occurrence of F off-types in any assessment of standards for registered seed stocks.

ACKNOWLEDGEMENT

This project was done in co-operation with the Oat Unit of the Cereal Crops Division. The author gratefully acknowledges assistance in all phases of the work. Seed samples of Clinton 59 were supplied by J. Whitmore, of the Canadian Seed Growers' Association, and G. Gilbert, of the Plant Products Division, Canada Department of Agriculture, Ottawa.

REFERENCES

1. Akerberg, E. Om fluorescensen hos gul-och vithavre samt hos vissa fatuoider. Nordisk Jordbrugsforskning 17:313-321. 1935.
2. Akerman, A. The breeding of oats. Svalof 1886-1946, pp. 98-112. Carl Bloms Boktryckeri, Lund, Sweden. 1948.
3. De Ment, J. Fluorescent chemicals and their applications. Chemical Publ. Co., Brooklyn, N.Y. 1942.
4. Finkner, R. E., H. C. Murphy, R. E. Atkins, and D. W. West, Varietal reaction and inheritance of fluorescence in oats. Agron. J. 46:270-274. 1954.
5. Gustafsson, A., and J. MacKey. Mutation work at Svalof. Svalof 1886-1946, pp. 338-357. Carl Bloms Boktryckeri, Lund, Sweden. 1948.
6. McClintock, B. The origin and behaviour of mutable loci in maize. Proc. Natl. Acad. Sci. U.S. 36:344-355. 1950.
7. Morey, D. D. The extent and causes of variability in Clinton oats. Research Bull. 363, Iowa State College, Ames, Iowa. 1949.
8. Schlehuber, A. M., B. C. Curtis, and R. M. Chatters. Progeny performance of fluorescence in Andrew oats. Agron. J. 48:381-383. 1956.
9. Sears, E. R. The aneuploids of common wheat. Research Bull. 572, Mississippi Agr. Expt. Sta. 1954.
10. Stanton, T. R. Oat identification and classification. Tech. Bull. 1100, U.S.D.A., Washington, D.C. 1955.

MOISTURE AND NITROGEN CONTENTS OF STEM TISSUES FROM SOLID- AND HOLLOW-STEMMED VARIETIES OF SPRING WHEAT AND THEIR RELATION TO SAWFLY RESISTANCE[1]

R. KASTING[2], A. J. MCGINNIS[3] AND E. L. LONGAIR[2]

Canada Department of Agriculture, Lethbridge, Alberta

[Received for publication November 5, 1957]

ABSTRACT

Except in the top internode, the moisture and nitrogen contents of the piths of two solid-stemmed, sawfly-resistant varieties of spring wheat, Rescue and Golden Ball, were not greatly different from those of the wall of the hollow-stemmed susceptible variety, Thatcher, at 80 and 98 days after seeding. The moisture and nitrogen contents of the walls varied, depending upon variety, internode, and date of harvest. The nodes of Golden Ball contained significantly greater quantities of moisture and nitrogen than did those of Rescue and Thatcher. The results indicate that, for the stages investigated, quantitative deficiencies in moisture and nitrogen contents of resistant varieties are not responsible for poor larval development.

INTRODUCTION

Hollow-stemmed varieties of *Triticum aestivum* L. are generally susceptible, and solid-stemmed varieties of *T. aestivum* and *Triticum durum* Desf. are generally resistant to the wheat stem sawfly, *Cephus cinctus* Nort. (4). Farstad (2) suggested that the pith of solid-stemmed varieties might be deficient in energy-providing foods and thus contribute to this resistance. Lopatecki *et al.* (3) found little qualitative difference in soluble carbohydrate content among varieties of wheat resistant and susceptible to the sawfly. Subsequent analyses on the same varieties* revealed no quantitative differences in carbohydrate content that could be associated with resistance. In addition to carbohydrate, growing sawfly larvae undoubtedly require a source of organic nitrogen. Should the pith of solid-stemmed varieties be deficient in nitrogen for the sawfly then this could contribute to resistance. The moisture content of the tissues may also affect larval development.

This paper compares the nitrogen and moisture contents of the nodes, and of the pith and wall tissues of individual internodes of two solid- and one hollow-stemmed spring wheat varieties at two stages of growth.

MATERIALS AND METHODS

Three varieties, Thatcher and Rescue (*Triticum aestivum*) and Golden Ball (*Triticum durum*), were grown on dry land at Lethbridge in randomized 8-row plots replicated four times. Samples were collected from all plots 80 days after seeding, at which time sufficient quantities of pith for the

[1] Contribution No. 380, Chemistry Division, and No. 3716, Entomology Division, Science Service, Canada Department of Agriculture, Ottawa, Canada.
[2] Head and Technician, respectively, Chemistry Section.
[3] Associate Entomologist, Crop Insect Section.
* *Unpublished*

TABLE 1.—PERCENTAGES OF MOISTURE IN THE PITH AND THE WALL FROM THE INTERNODES OF THREE SPRING WHEATS AT TWO DATES

	Days after seeding									
	80					98[1]				
	Internode					Internode				
	1	2	3	4	Mean[2]	1	2	3	4	Mean
Thatcher wall	52.7	54.1	56.3	46.7	52.4	29.7	45.2	51.4	44.6	42.7
Rescue wall	31.9	43.9	50.8	48.2	43.7	15.0	16.2	35.4	32.5	24.8
Rescue pith	20.2	41.0	42.0	44.7	37.0	—	16.2	30.0	32.7	26.3
Golden Ball wall	43.0	54.9	55.3	54.8	52.0	47.4	60.3	56.1	55.3	54.8
Golden Ball pith	46.8	64.1	63.9	63.2	59.5	40.5	70.5	67.5	59.2	59.4
Mean[3]	38.9	51.6	53.7	51.6	49.0	33.2	41.7	48.1	44.9	42.0

[1] Data from single block
[2] L.S.D. (P = 0.05) = 5.5%; (P = 0.01) = 7.3%
[3] 80-day collection only, L.S.D. (P = 0.05) = 4.9%; (P = 0.01) = 6.5%
Coefficient of variability for 80-day collection = 8.0%

TABLE 2.—PERCENTAGES OF NITROGEN ON A DRY-WEIGHT BASIS IN THE PITH AND THE WALL FROM THE INTERNODES OF THREE SPRING WHEATS AT TWO DATES

	Days after seeding									
	80					98[1]				
	Internode					Internode				
	1	2	3	4	Mean[2]	1	2	3	4	Mean
Thatcher wall	0.75	0.28	0.20	0.21	0.36	0.37	0.13	0.13	0.14	0.19
Rescue wall	0.78	0.34	0.23	0.23	0.40	0.28	0.14	0.11	0.12	0.16
Rescue pith	0.40	0.23	0.18	0.22	0.26	0.25	0.16	0.12	0.12	0.16
Golden Ball wall	1.12	0.43	0.28	0.27	0.53	0.62	0.34	0.25	0.24	0.36
Golden Ball pith	0.45	0.30	0.21	0.24	0.30	0.39	0.27	0.24	0.25	0.29
Mean[3]	0.70	0.32	0.22	0.23	0.37	0.38	0.21	0.17	0.17	0.23

[1] Data from single block
[2] L.S.D. (P = 0.01) = 0.07%
[3] 80-day collection only, L.S.D. (P = 0.01) = 0.03%
Coefficient of variability for 80-day collection = 5.4%

analyses were readily obtained from each of the internodes of the solid-stemmed varieties. Rescue and Thatcher were in the soft dough stage, and Golden Ball was in the early milk stage. A single replicate of each variety was also sampled 98 days after seeding, when Thatcher and Rescue were nearly ripe and Golden Ball was in the soft dough stage.

Twenty-five stems selected at a uniform stage of growth from the middle six rows of each plot were cut off at ground level. From these, 10 of the most similar stems were chosen per sample; the leaves were removed and the stems were divided into nodes and internodes. For the 10 stems all of the nodes were combined but the internodes, numbered consecutively from the head down, were treated separately. The pith was stripped from the wall of the solid-stemmed varieties. The pith and wall tissues from each sample weighed about 0.5 gram and from 2 to 10 grams, respectively. The samples were dried at 135° C. for moisture determination, and duplicate samples were analysed for nitrogen by the micro-Kjeldahl procedure (1). The significance of differences was determined by analyses of variance. As only one block was sampled on the second date the results were not analysed statistically.

RESULTS

Table 1 shows that between the two harvest dates the moisture content decreased in Thatcher and Rescue stems but not in those of Golden Ball, a later-maturing variety. The moisture content of Rescue wall was significantly higher than that of the pith at the early harvest date; this difference tended to decrease with ripening. Conversely, Golden Ball wall had a significantly lower moisture content than the pith. Except for Thatcher wall the top internode had a significantly lower moisture content than the other internodes. In general these trends were apparent in the later collection.

Table 2 shows that there was a general decrease in the percentage of nitrogen in the stem tissues as the plants matured. In the earlier collection the nitrogen content of the stems of the three varieties decreased progressively to the third internode and then levelled off. In the later collection the top internodes still contained the highest percentage of nitrogen; the other internodes were generally similar in nitrogen content. The percentages of nitrogen in Rescue and Golden Ball piths were not significantly different from those of Thatcher walls on the first date except for the top internode. There was no significant difference in the nitrogen content of Thatcher and Rescue walls when compared on an internode basis; Golden Ball wall contained significantly higher quantities of nitrogen than did Thatcher. Similar trends were apparent at the later date. At 98 days the pith of Golden Ball stems appeared to contain equal or greater quantities of nitrogen than either tissue of the other varieties.

A recalculation of the nitrogen content per unit of fresh weight showed that there was no significant difference between the walls of Thatcher and the piths of the other varieties for the second, third, and fourth internodes. In the top internode Rescue and Golden Ball piths had significantly less nitrogen than did Thatcher wall.

TABLE 3.—PERCENTAGES OF MOISTURE AND NITROGEN IN THE NODES OF THREE SPRING WHEATS AT TWO DATES

Days after seeding	Variety	Moisture	Nitrogen[1]
80	Thatcher	54.4	0.59
	Rescue	52.4	0.62
	Golden Ball	61.3	0.82
	L.S.D. (P = 0.01)	4.1	0.09
98[2]	Thatcher	54.5	0.40
	Rescue	54.4	0.33
	Golden Ball	64.5	0.52

[1] Dry-weight basis
[2] Data from single block

As shown in Table 3 the moisture contents of the nodes from each variety appeared similar at the two harvest dates whereas the nitrogen contents decreased. On the first date the percentages of moisture and nitrogen in Thatcher and Rescue nodes were similar but significantly less than those of Golden Ball.

DISCUSSION

Except for the top internode, the moisture and nitrogen contents of the pith of the sawfly-resistant, solid-stemmed varieties were not greatly different from those of the walls of the sawfly-susceptible, hollow-stemmed variety Thatcher. Moreover, preliminary analyses of the 80-day old plants for total alcohol-soluble carbohydrates showed that the pith of these two varieties contained as much carbohydrate or more than the walls of corresponding internodes from Thatcher. If the composition of the stem wall is representative of what the feeding larvae obtain from the wall, then for these stages of plant growth there were no gross quantitative deficiencies of moisture, nitrogen, or carbohydrate in the pith that might account for poor development of the larvae. Furthermore, no deficiencies in moisture or nitrogen were apparent in the nodes of solid-stemmed varieties. Studies at the Lethbridge laboratory by N. D. Holmes and C. W. Farstad indicate that after a minimum feeding period the larvae may mature under adverse conditions. The present data along with these biological observations suggest that starvation of the larvae in the later stages of their growth is not a factor in the resistance exhibited by the solid-stemmed varieties.

The moisture content of Thatcher stems was intermediate between the values for the piths of the other varieties. Furthermore, the differences in moisture and nitrogen contents were as great or greater between the top two internodes within a variety as between tissues of the different varieties. In wheat plants at the stages of growth investigated, the larvae are not restricted to feeding in the top internode and are generally found lower in the stem. It would appear, therefore, that resistance cannot be attributed to quantitative differences in nitrogen or moisture intake by the larvae unless the quantities of plant material consumed differ among varieties. It is possible, of course, that qualitative differences in the nitrogen fractions are important.

REFERENCES

1. Association of Official Agricultural Chemists. Official methods of analysis. 7th ed. Washington, D. C. 1950.
2. Farstad, C. W. A study of the development of Western wheat stem sawfly, *Cephus cinctus* Nort., in various host plants as an index of resistance. Abstract, Ph.D. thesis, Iowa State College. 1940.
3. Lopatecki, L. E., E. L. Longair, and C. W. Farstad. Soluble carbohydrates of wheat stems and leaves. Can. J. Botany 35 : 9-12. 1957.
4. Platt, A. W., and C. W. Farstad. The reaction of wheat varieties to wheat stem sawfly attack. Sci. Agr. 26 : 231-247. 1946.

POTASSIUM IN PLANT METABOLISM. I. EFFECTS OF LIGHT ON THE MINERAL COMPOSITION OF NORMAL AND POTASSIUM-DEFICIENT WHEAT SEEDLINGS[1]

G. M. WARD

Canada Department of Agriculture, Ottawa, Ontario

[Received for publication November 4, 1957]

ABSTRACT

Normal and potassium-deficient wheat seedlings were grown in sand culture under controlled environmental conditions in a growth chamber. Successive crops were subjected to varying photoperiods and light intensities. Chemical analysis of tissues of the 14-day seedlings indicated that any restriction of light intensity or duration resulted in higher levels of potassium in the plant, when potassium was available. Phosphorus decreased with increasing photoperiod. Levels of calcium, magnesium, iron, copper and manganese were not directly related to illumination. Chlorosis due to potassium deficiency showed a correlation with high phosphorus/iron ratios.

INTRODUCTION

The role of potassium in plant metabolism has not yet been defined, although its importance for the growing plant is universally recognized. A deficiency of potassium in plant tissues results in gross disturbances of the biochemical composition which have been observed in many species. These, of course, are accompanied by visible symptoms such as retarded growth and other characteristic alterations of form and structure. A study of the biochemistry of disordered tissues of deficient plants constitutes one approach to the problem of mineral function in metabolism and is the subject of a series of investigations now in progress in this laboratory.

In such a study it is highly desirable to eliminate environmental variables where possible, and to employ a plant tissue which has a reasonably reproducible degree of physiological uniformity. An approximation of these conditions has been obtained by growing wheat seedlings in sand culture in a growth chamber. However, experience has shown that plants produced in the artificial environment of a greenhouse or a growth chamber are not identical in form or composition with those grown under natural field conditions. It has been necessary, therefore, to study and assess the effects of individual environmental factors in the production of normal, healthy, chamber-grown plants to obtain a standard of comparison.

This report presents the results of a study of the effects of light upon the nutrition of normal and potassium-deficient wheat seedlings. The subject of the influence of light upon plant nutrition has been reviewed by Withrow (10). The present experiments differ from those of other investigators (4, 6, 8) mainly in the precise nature of the control of environmental factors and in the number of nutrient elements studied.

[1] Contribution No. 382, Chemistry Division, Science Service, Canada Department of Agriculture, Ottawa, Ont.

MATERIALS AND METHODS

Wheat seedlings of the variety *Triticum aestivum*, Acadia were grown in washed quartz sand in plastic containers in a growth chamber. Conditions in the chamber were maintained at 70°F. and 55 per cent relative humidity, fresh air being supplied at the rate of one complete change per minute. Light was supplied by cool white fluorescent tubes and the photoperiod was controlled by an electric timer. The maximum illumination was 1500 foot-candles as measured by a General Electric photocell light meter.

The plants were fed daily by keeping the sand moist with Hewitt's complete standard nutrient solution (3) using the lowest recommended level of potassium, 78 p.p.m. Potassium-deficient seedlings were produced by substituting an equimolar amount of $NaNO_3$ for KNO_3 in the nutrient solution. One hundred and twenty-five plants were grown in each container and all treatments were applied in triplicate. The first experiment of the series was repeated, with essentially the same results. Uniform illumination of the plants was ensured by using only those portions of the growth chamber where the light intensity was maximum and by periodic rotation of the containers. The following description of the progress of plant development during 14 days of seedling growth is presented here since an understanding of the physiological and morphological ontogeny of the normal and deficient plants is essential for an adequate interpretation of some of the biochemical data that will be presented in later reports.

Coleoptiles emerged on the second day after planting. The first leaf attained almost full growth about the tenth day, at which time the second leaf was beginning to emerge. On the fourteenth day the plants were harvested when the second leaf had fully expanded and the third leaf was beginning to appear. In the potassium-deficient treatment the first leaf developed in an apparently normal fashion up to the tenth day, except for a very slight decrease in size. Then, as the second leaf began to emerge, the first leaf rapidly turned yellow from the tip downwards and by the fourteenth day the tip was brown and necrotic. The development of the second leaf was much retarded and in some instances a slight yellowing occurred by the fourteenth day. The whole plant was appreciably stunted.

At harvesting the plants were cut off at sand level and divided into three parts—*first leaf*, *second leaf* and *stem*. Small third leaves, if present, were included with the second leaves. Abnormal and abortive plants were discarded. The samples were weighed, dried at 80°C., reweighed and ground for subsequent chemical analysis. The number of plants in each sample was recorded. The dried tissue was ashed at 550°C. A hydrochloric acid extract of the ash was prepared and analysed for mineral constituents by methods previously outlined (9).

Two experiments are described in this report. In the first, three crops of seedlings were produced with photoperiods of 6, 12, and 18 hours and a light intensity of 1000 f.c. Each crop included normal plants and potassium-deficient plants. In each instance harvesting was started 2 hours after the change from darkness to light. The plant tissue was analysed for K, Ca, Mg, P, Fe, Cu, Mn. The second experiment was a

comparison of the mineral composition of plants grown under conditions of constant photoperiod, 12 hours, but with light intensities of 750, 1000, and 1500 f.c. Normal and potassium-deficient plants were produced in each case but analysis of the tissue included only determinations of K and Ca.

RESULTS

Due to considerations of ontogeny and function the nutritional relationships at any one point of time may vary markedly in the three regions of the wheat seedling—first leaf, second leaf and stem. In order to obtain a clear picture of these relationships the analytical data must be considered both as a percentage of the total weight of tissue and in terms of the total quantity of each constituent per plant. These calculations have been made and conclusions have been drawn from both sets of data.

The results of the first experiment are shown in Table 1 as per cent of dry weight and a summary of the total weight of each constituent per plant is given in Figure 1.

Green Weight: This measurement, which may be considered as a general index of growth, increased with increasing photoperiod except in the first leaf, where it varied slightly but irregularly.

Dry Weight: Increasing photoperiod produced relatively larger increases in dry weight than in green weight. This was found to be true with both total and per cent dry weight in all plant parts. This observation illustrates the well-known relationship of the dependence of growth and dry matter synthesis on light. The same trends were observed in both normal and potassium-deficient plants. The latter, however, were stunted plants and produced much less growth and dry matter. They had a slight water deficit so that the percentage of dry weight was somewhat higher in potassium-deficient plants.

Potassium: The total amount of potassium in all parts of a normal plant increased with increasing photoperiod due to the substantial increase in growth. The percentage of potassium, however, decreased with increasing photoperiod. In a potassium-deficient plant there was no consistent pattern of change related to photoperiod. The only source of potassium available to potassium-starved plants grown in sand culture is the amount present in the seed before planting. In the wheat seedling this quantity, which amounts to about 200 μg., is rapidly transferred almost entirely to the first leaf during the first 10 days of growth. Then, as the second leaf develops, most of this potassium is mobilized and transferred to the rapidly growing regions in the second leaf and stem tip. Sometimes the first leaf is left with as little as 10 μg. of K by the fourteenth day of growth, while the second leaf may have ten times that amount. In previous experiments it has been shown that the summation of all the quantities of potassium found in the various portions of a potassium-deficient wheat seedling. including the root, is approximately equal to the total quantity found in a seed.

Calcium: Percentage of calcium showed no direct relation to changes in photoperiod either in normal or potassium-deficient plants. Increase in total calcium in second leaves and in the whole plant was simply a re-

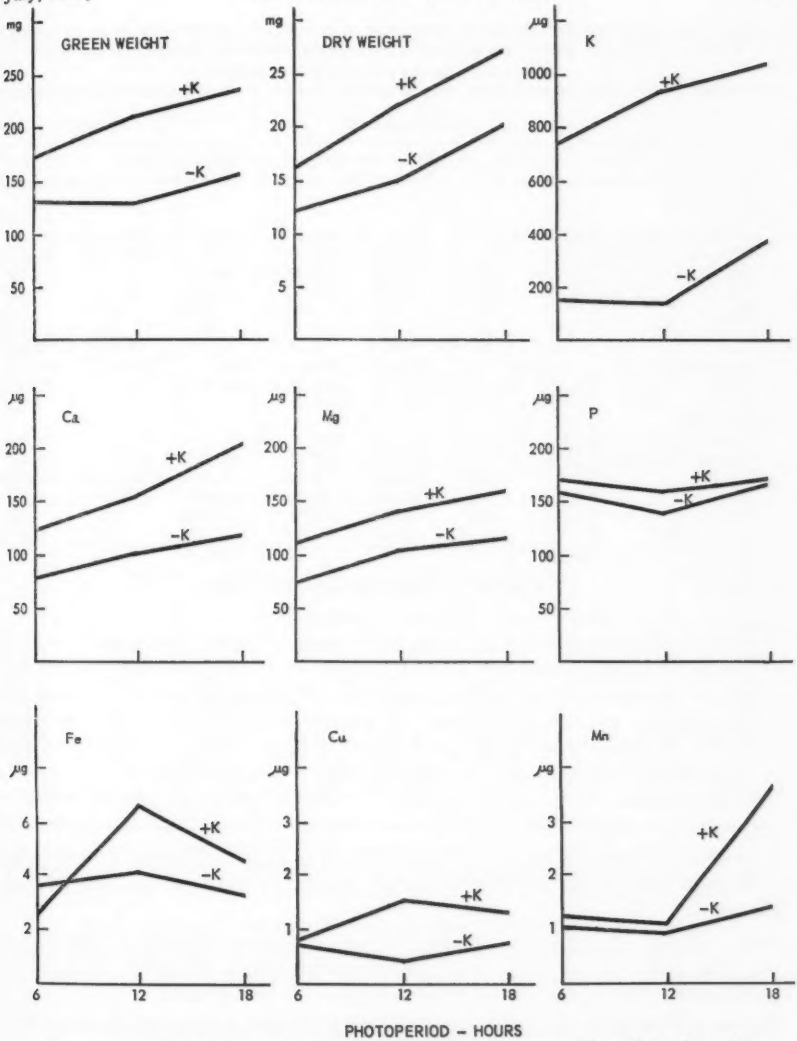

FIGURE 1. Effect of increasing photoperiod on the composition of 14-day wheat seedlings grown in sand culture at a light intensity of 1000 foot-candles, expressed as total weight per plant.

flection of the increase in general growth. Potassium deficiency produced no increase in calcium content.

Magnesium: Magnesium content of the wheat seedling was likewise not related to photoperiod or to potassium deficiency.

Phosphorus: Percentage of phosphorus showed a regular decrease with increasing photoperiod in all parts of both normal and potassium-deficient seedlings. Percentages in deficient plants were consistently higher

TABLE 1.—ANALYSIS OF FOURTEEN-DAY WHEAT SEEDLINGS GROWN IN SAND CULTURE UNDER DIFFERENT PHOTOPERIODS AT A LIGHT INTENSITY OF 1000 FOOT-CANDLES
(expressed as per cent of dry weight)

Constituent	+ K Treatment			− K Treatment		
	6 hr.	12 hr.	18 hr.	6 hr.	12 hr.	18 hr.
First Leaf						
Green wt./plant (mg.)	45.7	51.5	46.1	43.0	32.1	30.9
Dry wt. (% of G.W.)	9.5	9.9	11.2	10.0	12.7	14.0
K	2.82	2.80	1.87	0.51	0.31	0.49
Ca	0.82	1.22	0.62	0.59	0.64	0.47
Mg	.73	.77	.86	.49	.67	.73
K/Ca+Mg	1.82	1.41	1.26	.47	.24	.41
P	0.67	0.48	0.31	1.04	0.81	0.64
Fe (p.p.m.)	254	290	280	338	292	232
P/Fe	26.4	16.5	11.1	30.8	27.7	27.6
Second Leaf						
Green wt./plant (mg.)	72.0	93.8	118.2	50.7	59.8	74.5
Dry wt. (% of G.W.)	10.4	11.6	12.7	10.8	12.3	13.7
K	4.44	4.01	3.67	1.33	0.81	1.70
Ca	0.61	0.52	0.59	0.62	0.47	0.66
Mg	.55	.57	.51	.59	.68	.52
K/Ca+Mg	3.83	3.68	3.34	1.10	.70	1.44
P	1.24	0.77	0.72	1.52	0.90	0.95
Fe (p.p.m.)	194	152	127	252	230	140
P/Fe	64.0	50.6	56.7	60.3	39.1	67.8
Stem						
Green wt./plant (mg.)	52.0	63.7	68.5	34.0	34.8	49.4
Dry wt. (% of G.W.)	8.3	9.5	10.2	8.2	9.5	10.8
K	6.26	5.73	5.41	1.76	1.71	3.14
Ca	0.96	0.56	1.18	0.82	1.23	0.54
Mg	.86	.67	.54	.86	.81	.53
K/Ca+Mg	3.44	4.66	3.15	1.05	1.19	2.93
P	1.02	0.82	0.65	1.17	1.08	0.74
Fe (p.p.m.)	244	232	167	333	370	152
P/Fe	41.8	38.9	38.9	35.2	29.2	48.7

than those in normal plants. This resulted in total quantities which were strikingly similar in the two series of plants, as may be seen clearly in Figure 1.

Iron, Copper, Manganese: There was no consistent pattern of change in the absorption of any of these micronutrient elements related to changes in photoperiod either in normal or potassium-deficient plants.

Ratios: Two sets of ratios are included in Table 1, namely K/Ca+Mg and P/Fe. There was no relationship between these figures and the changes in photoperiod. The first-mentioned ratio varies, of course, with potassium treatment, being much lower in all parts of potassium-deficient plants.

The results of the second experiment are reported in Table 2 as per cent of dry weight. These figures show that more dry matter was built up in leaf tissue but not necessarily in stems under conditions of higher light intensity. Percentage of potassium decreased in normal plants but increased in potassium-deficient plants with increasing light intensity. Percentage of calcium was not related to changes in light intensity.

TABLE 2.—ANALYSIS OF FOURTEEN-DAY WHEAT SEEDLINGS GROWN IN SAND CULTURE UNDER A TWELVE-HOUR PHOTOPERIOD AT DIFFERENT LIGHT INTENSITIES
(expressed as per cent of dry weight)

Constituent	+ K Treatment			− K Treatment		
	750 f.c.	1000 f.c.	1500 f.c.	750 f.c.	1000 f.c.	1500 f.c.
First Leaf						
Green wt./plant (mg.)	47.5	51.5	60.9	33.4	32.1	39.2
Dry wt. (% of G.W.)	9.2	9.9	10.2	11.1	12.7	12.0
K	3.50	2.80	2.53	0.14	0.31	0.76
Ca	1.24	1.22	1.30	0.99	0.64	1.24
Second Leaf						
Green wt./plant (mg.)	73.7	93.8	109.0	44.0	59.8	58.5
Dry wt. (% of G.W.)	11.0	11.6	13.1	12.3	12.3	12.5
K	4.36	4.01	3.69	0.68	0.81	1.50
Ca	0.70	0.52	0.56	0.75	0.47	0.58
Stem						
Green wt./plant (mg.)	60.9	63.9	53.4	34.0	34.8	29.1
Dry wt. (% of G.W.)	10.3	9.5	10.8	12.6	9.5	13.6
K	6.03	5.73	4.84	0.82	1.71	2.44
Ca	0.80	0.56	0.46	0.75	0.58	0.54

DISCUSSION AND CONCLUSIONS

Data presented in the foregoing sections have shown that, under conditions of reduced light intensity or duration, levels of potassium in plant tissues were consistently increased, provided the plants were grown in a medium that contained an adequate supply of the element. This relationship has been observed before by several workers (6) but has not been reported for plants grown in a controlled environment. When potassium was deficient in the growth medium, the effect of light upon potassium absorption was obscured. The apparent anomaly in potassium-deficient plants, particularly noticeable in Table 2, which shows an increase in potassium level with increasing exposure to light, may be an effect of translocation rather than absorption but an adequate explanation has not yet been found.

The levels of phosphorus in the wheat plant varied in a manner similar to those of potassium. Increased exposure to light depressed the relative uptake of this element with resulting lower percentages in all parts of the plant.

Light affects mineral nutrition only in an indirect manner by way of its direct effects upon such natural processes as photosynthesis, chlorophyll synthesis, photoperiodism or transpiration. The most conspicuous indirect role of light in mineral metabolism is through photosynthesis. When the light energy supplied to plants is increased in any way, the rate of carbohydrate synthesis increases, the amount of dry matter is higher, the plants are larger, total transpiration is greater, and the absorption of mineral nutrients is stimulated. This sequence of events is illustrated by the data presented here. In both series the dry weight of the wheat plants increased with increasing light both as percentage and as total weight per plant. The total uptake of minerals was likewise increased. The fact that

potassium and phosphorus percentages changed in the other direction is evidence of the complex nature of the changes being studied and suggests the influence of more than one environmental or metabolic factor.

Thermal effects of increased light may be manifested under natural conditions in enhanced mineral absorption because of higher transpiration rates. In a controlled environment, such as that used in this investigation, these effects would be minimized.

Throughout this report the term "photoperiod" has been used to denote the number of hours of daily exposure of wheat plants to light of uniform intensity. The simple design of the experiment, however, does not permit any conclusions to be drawn regarding the effect of the photoperiodic mechanism. Withrow (10) has indicated that investigators have failed to find any correlation between the photoperiodic induction mechanism and mineral nutrition. This is obviously a field that requires further study. It seems apparent, however, that the greater part of the effect observed in this investigation is due to the differences in the total amounts of incident energy falling upon the plants rather than to photoperiodic stimulation.

The data presented here do not show any correlation between calcium or magnesium levels in the tissues and the amount of light supplied to the plant. This agrees with the findings of others (7). A similar lack of correlation in reference to iron, manganese and copper is an observation which has not been previously reported.

The interrelationship or balance between various nutrient elements is currently being considered as an important factor in plant nutrition. It has often been stated that there is an antagonistic effect between potassium on the one hand and calcium and magnesium on the other. For example, McCalla and Woodford (5) reported a marked increase in calcium and magnesium content of the dry matter of potassium-deficient wheat plants. Such a relationship was not observed in the plants of the present experiment. The ratio K/Ca+Mg is influenced almost entirely by the variations in potassium content already noted. A great deal of confusion still exists in the interpretation of analytical data on this subject. It has been reported that calcium can either increase or decrease potassium absorption, depending on the concentration of potassium. It has also been shown that the level of sodium in the tissue has an effect upon the calcium-potassium relationship.

Another nutrient balance which has recently been advocated by DeKock (1, 2) is the P/Fe ratio. He claims that leaves exhibiting chlorosis of various types have a consistently higher P/Fe ratio than normal green leaves. The calculations presented in Table 1 show that the chlorosis due to potassium deficiency might fall into this category. The first leaf of the 14-day potassium-deficient seedling is the only part of the plant which is chlorotic at that stage of growth, and in Table 1 the ratio values for deficient first leaves are all higher than those of normal first leaves. The relationship in other parts of the plant where chlorosis does not occur is not consistent.

REFERENCES

1. DeKock, P. C., and A. Hall. The phosphorus-iron relationship in genetical chlorosis. Plant Physiol. 30:293-295. 1955.
2. DeKock, P. C. Heavy metal toxicity and iron chlorosis. Ann. Botany, N.S. 20: 133-141. 1956.
3. Hewitt, E. J. Sand and water culture methods used in the study of plant nutrition. Tech. Comm. 22, Commonwealth Agricultural Bureaux, England. 1952.
4. Johnston, E. S., and D. R. Hoagland. Minimum potassium level required by tomato plants grown in water cultures. Soil Sci. 27:89-109. 1929.
5. McCalla, A. G., and E. K. Woodford. The effect of potassium supply on the composition and quality of wheat. Can. J. Research, C, 13:340-354. 1935.
6. Miller, E. V., and T. J. Army. Effect of environment on the potassium and sodium contents of plants. U.S.D.A. Southern Cooperative Series Bull. 36, pp. 118-154. 1954.
7. Peterson, W. J., and H. F. Krackenberger. Effect of environment on the calcium content of plants. U.S.D.A. Southern Cooperative Series Bull. 36, pp. 77-97. 1954.
8. Tanada, T. Utilization of nitrates by the coffee plant under different sunlight intensities. J. Agr. Research 72:245-258. 1946.
9. Ward, G. M., and F. B. Johnston. Chemical methods of plant analysis. Contribution 238, Chemistry Div., Can. Dept. Agr. 1953.
10. Withrow, R. B. Light as a modifying influence on the mineral nutrition of plants. Mineral nutrition of plants, pp. 389-410. Univ. Wis. Press, Madison, Wis. 1951.

THE USE OF A VARIABLE DOSAGE SPRAYER IN WEED CONTROL RESEARCH[1]

GEORGE FRIESEN[2]

The University of Manitoba, Winnipeg, Manitoba

[Received for publication April 12, 1958]

ABSTRACT

A variable dosage sprayer was used in a series of weed control experiments. These tests demonstrated the diversity of problems that can readily be studied with the aid of such a machine. Undoubtedly further applications will be found as the machine becomes more widely used.

The machine was found to have several advantages over conventional plot sprayers used in weed research:

1. The accuracy with which the toxicity or selectivity of a herbicide could be measured.
2. The suitability for studies on the effect of admixtures of herbicides such as oil in the carrier.
3. A substantial reduction in the number of plots needed to obtain the required information with a resulting saving of time and effort.

INTRODUCTION

It has long been recognized that one of the inherent problems in weed research is the large number of plots needed to compare adequately the effectiveness of various concentrations of a herbicide under test. A variable dosage sprayer developed at the Chesterford Park Research Station, Fisons Pest Control Ltd., England (3) shows promise of overcoming this difficulty. The essential feature of this machine (designated as the Chesterford Logarithmic Sprayer) is that it sprays a continuously decreasing dosage of a herbicide as it moves along an experimental plot. Theoretical principles underlying the operation of this machine have been outlined by Brunskill (1) and the first large-scale field trials were reported by Wrigley (4).

A Chesterford Logarithmic sprayer was made available to the Plant Science Division, The University of Manitoba, for the 1957 spraying season. The sprayer, a standard production model, was mounted on the rear of a Land Rover pick-up (Figure 1). The vehicle was equipped with a constant speed governor and rear power take-off shaft. This paper discusses a procedure for the calibration of the sprayer and includes the results obtained in four weed control experiments in which this sprayer was used.

CALIBRATION OF THE SPRAY UNIT

In each of the four experiments described in this paper, the initial dosage of a herbicide was arbitrarily chosen at 8 pounds of active ingredient per acre. Land speed of the vehicle was calibrated at 3.26 miles per hour with a power take-off speed of 470 revolutions per minute. At this speed the sprayer gear pump delivered 3.64 gallons of water per minute at a pressure of 38 pounds per square inch. Total volume of spray deposited was 30.84 gallons per acre.

[1] Contribution from the Division of Plant Science, University of Manitoba, Winnipeg, Man.
[2] Associate Professor, Weed Research.

FIGURE 1. A Chesterford Logarithmic sprayer mounted on a Land Rover pick-up.

The half-dosage distance was calculated from the formula: half-dosage distance = .0597 vt yd., where "v" equals the land speed (in miles per hour) of the vehicle and "t" equals the time in seconds to spray two Imperial gallons (2). Using this formula the half-dosage distance was calculated to be 6.42 yards. Therefore, each time the sprayer covered this distance the dosage was reduced by one-half, the decrease being exponential and not linear.

In the four experiments in which this sprayer was used the experimental plots were 14 × 77 feet in size, the width allowing for one boom width of the sprayer. The length of 77 feet allowed for four "half-dosage distances", the minimum dosage, therefore, being one-sixteenth of the maximum dosage. The dosage at any intervening point could likewise be determined.

The dosages at various distances along the experimental plot were calculated logarithmically and are presented in Table 1.

EXPERIMENT A

The Effect of TCA (Sodium Trichloroacetate) on Green Foxtail at Different Growth Stages

The use of TCA for the control of green foxtail (*Setaria viridis* (L.) Beauv.) in flax and several other crops is now an accepted farm practice. The recommendations for its use are as follows: "TCA at four to six pounds per acre should be applied when green foxtail is in the early seedling stages before it has developed four leaves". Little information is available regarding the dosages required to give satisfactory control at other growth stages. The objective of this project was to determine the susceptibility or resistance of green foxtail at various growth stages to TCA treatment. TCA at continuously decreasing rates from 8 pounds per acre to one-half

TABLE 1.—DOSAGES OF A HERBICIDE AT VARIOUS DISTANCES ALONG AN EXPERIMENTAL PLOT WHEN THE HALF-DOSAGE DISTANCE IS 6.42 YARDS AND THE MAXIMUM DOSAGE IS 8 POUNDS PER ACRE

Distance from beginning of plots (yd.)	Fraction of maximum dosage	Dosage (lb. /a.)
0	1.00	8.00
1	.89	7.12
2	.80	6.40
3	.72	5.76
4	.65	5.20
5	.57	4.56
6	.52	4.16
6.42	.50	4.00
7	.47	3.76
8	.42	3.36
9	.38	3.04
10	.34	2.72
11	.31	2.48
12	.27	2.16
12.84	.25	2.00
13	.25	1.99
14	.22	1.76
15	.20	1.60
16	.18	1.44
17	.16	1.28
18	.15	1.20
19	.13	1.04
19.26	.125	1.00
20	.12	.96
21	.11	.88
22	.09	.72
23	.08	.68
24	.08	.64
25	.07	.56
25.68 (77.04 ft.)	.0625	.50

pound per acre (acid equivalent) was sprayed at approximately one-week intervals on a green foxtail infested area at Winnipeg. Treatments were conducted in duplicate and the experiment involved only 12 plots.

The dates of spraying, stages of weed growth, and minimum dosage of TCA giving satisfactory (95 per cent) control are presented in Table 2.

It will be noted that the dosage required to give satisfactory control increased progressively as growth advanced. When the weed reached the heading stage, it became highly resistant. The value of such information from the standpoint of practical weed control recommendations can hardly be exaggerated. The continuous gradation of rates permitting the pinpointing of satisfactory control could not be duplicated easily with a conventional plot sprayer and would require the use of hundreds of experimental plots.

TABLE 2.—EFFECT OF TCA ON GREEN FOXTAIL AT VARIOUS GROWTH STAGES

Date of spraying	Stage of green foxtail growth	Minimum dosage of TCA (acid equivalent) resulting in satisfactory control
		lb./a.
June 13	Pre-emergence	1.35
June 21	½—1 in., 1—3 leaves	2.70
July 2	1—2½ in., 2—4 leaves	2.95
July 12	2—4 in., 4—5 leaves	3.10
July 17	6—8 in., trace of heading	5.80
July 23	10—16 in., fully headed	8.00

EXPERIMENT B

The Effect of Several New Herbicides on Wild Oats under Different Soil Conditions

In recent years weed research workers have begun to investigate the possibility of using herbicides for the selective control of wild oats (*Avena fatua* L.) in field crops. The most promising herbicides must be applied as pre-planting or pre-emergence treatments and the influence of soil type may be of utmost importance. The precise determination of the inter-relationship between wild oat response and soil type has been greatly simplified through the use of a variable dosage sprayer.

A comprehensive series of experiments were conducted in 1957 on the control of wild oats in field crops. Five herbicides which had shown promise in preliminary trials were tested at five sites representing the chief soil types in Manitoba. Fields selected were known to be heavily infested with wild oats and were seeded to wheat, barley or flax. Herbicides included in these tests were EPTC, (ethyl N,N-di-n-propylthiolcarbamate), CDAA (2-chloro-N,N-diallylacetamide), FW-433, CP-13042, and CP-6840 (three experimental herbicides, the chemical compositions of which had not been released). These herbicides were applied at continuously decreasing dosages from 8 pounds to one-half pound per acre, active ingredient. Treatments were conducted in duplicate at each location and soil incorporation was carried out with available farm equipment.

The soil types, methods of incorporation and minimum herbicidal dosages giving satisfactory (95 per cent) wild oat control are presented in Table 3.

The chemical CDAA, which showed up as one of the best at Winnipeg, gave varying results at other locations. On the heaviest soil (Osborne clay) and the lightest soil (Stockton sandy loam) CDAA was ineffective. The causes for the inconsistency in results require further study. The consistency of EPTC under the different soil conditions is evident and encouraging. Apparently the toxicity of this herbicide is not greatly influenced by soil type when applied as a pre-planting treatment. The other three herbicides, F-433, CP-13042, and CP-6840, proved non-toxic to wild oats at all rates applied and have been omitted from the table.

TABLE 3.—RESPONSE OF WILD OATS TO SEVERAL HERBICIDES AT DIFFERENT LOCATIONS IN MANITOBA, 1957

Location	Soil type	Method of incorporation	Minimum dosage resulting in satisfactory control of wild oats	
			EPTC	CDAA
			lb./a.	lb./a.
Winnipeg	Riverdale silty clay	Rototiller	2.15	2.90
Glenboro	Stockton sandy loam	One-way	1.80	8.00*
Dauphin	Dauphin clay	Wide-level disker	3.00	3.40
Swan River	Valley clay loam	Wide-level disker	3.30	5.50
Morris	Osborne clay	Tandem disk (twice)	3.20	8.00*

* 8 lb./a. was highest dosage used and failed to give satisfactory control.

EXPERIMENT C

Comparing the Effectiveness of Several Pre-emergence Herbicides for Weed Control in Corn

Six herbicides, applied as pre-emergence treatments, were compared as to their effectiveness in controlling several weed species in corn. The experiment was carried out at two locations, Winnipeg (Riverdale clay loam) and Morden (Almasippi fine sandy loam). Canning corn (variety Seneca Hybrid) was planted on June 1 and June 6 at Morden and Winnipeg respectively, and herbicidal treatments were made one week later. Herbicides included in the test were Simazin (2-chloro-4, 6-bis(ethylamino)-S-triazine, CDAA, CDAA-T (a newer formulation of CDAA), CDEC (2-chloroallyl diethyldithiocarbamate), Emid (2,4-dichlorophenoxyacetamide), and EPTC. Herbicides were applied one week after planting at decreasing dosages from 8 pounds to one-half pound (active ingredient) per acre using the variable dosage sprayer. Treatments were conducted in duplicate with untreated plots adjoining each treated plot.

The effect of these herbicides on weed species prevalent in the areas is presented in Table 4.

Wild oat response at Winnipeg was comparable for all herbicides with the exception of CDEC. Wild mustard varied greatly in resistance to these herbicides, being highly susceptible to CDAA-T and Emid, but showing considerable tolerance to CDAA and EPTC. Green foxtail response also varied considerably between herbicides and locations. Of particular interest was the variation in response to CDAA, CDAA-T and Emid. Whereas comparatively low rates of these herbicides gave satisfactory control at Winnipeg, poor results were obtained at Morden. Simazin and EPTC were not significantly affected by soil type as indicated by green foxtail response at the two locations. Only one herbicide caused some injury to the corn at rates used. Emid at rates exceeding 5.2 pounds per acre resulted in abnormalities and significant reductions in yield.

TABLE 4.—MINIMUM DOSAGES (ACTIVE INGREDIENTS) RESULTING IN SATISFACTORY CONTROL OF PREVALENT WEED SPECIES AT WINNIPEG AND MORDEN, MANITOBA

Herbicide	Winnipeg			Morden
	wild oats	wild mustard	green foxtail	green foxtail
	lb./a.	lb./a.	lb./a.	lb./a.
Simazin	3.36	1.28	2.72	2.79
CDAA	3.36	5.36	.50	8.00*
CDAA-T	3.40	.59	.89	5.20
CDEC	8.00*	2.72	8.00*	8.00*
Emid	3.30	.50	2.16	8.00
EPTC	3.78	8.00*	1.76	1.80

* Control not satisfactory at highest dosage used.

It is readily evident that this volume of information would not have been obtainable with a conventional plot sprayer. In previous screening trials only two or three treatment rates could be included and sometimes the most effective dosages were unknowingly omitted.

EXPERIMENT D

Comparison of Oil and Water as Carriers for IPC and CDAA

IPC (isopropyl-N-phenylcarbamate) and CDAA both show promise for the control of wild oats in sugar-beets. There has been some speculation as to the use of an oil carrier in the solution to enhance the activity and residual effect of these herbicides. This experiment was conducted in an attempt to establish the optimum amount of oil in the solution and thereby derive maximum weed control.

IPC and CDAA, each at 3 pounds per acre (active ingredient) were applied as pre-planting treatments to sugar beets on wild oat infested land. The amount of diesel fuel in the spray solution varied from 8 gallons per acre to one-half gallon per acre, using the variable dosage sprayer. Total volume of spray solution was maintained constant at 30.84 gallons per acre. Four replications were used and herbicidal treatments were incorporated with a rototiller to a depth of 2 to 3 inches immediately after spraying. Untreated plots were located adjacent to treated plots.

It was apparent throughout the season that both herbicidal treatments resulted in a satisfactory control of wild oats regardless of the amount of diesel fuel in the carrier. Counts on treated and adjacent untreated plots substantiated the visual observations. It was, therefore, concluded that, in this particular test, diesel fuel within the dosage spectrum used did not increase the effectiveness of IPC or CDAA. This may well have saved a substantial volume of work and demonstrated the usefulness of the variable dosage sprayer in studying the effect of admixtures of herbicides in weed control.

ACKNOWLEDGEMENTS

The author wishes to thank Fisons Pest Control Ltd., England, for making the sprayer available for evaluation, and the Manitoba Department of Agriculture for providing the necessary funds to purchase the Land Rover pick-up. Thanks are also due the many commercial firms who so kindly contributed the chemicals for the experiments described in this paper.

REFERENCES

1. Brunskill, R. T. A variable dosage sprayer for agricultural use. J. Agr. Eng. Research Vol. 2, No. 2. 1957.
2. Fisons Pest Control Ltd. chesterford logarithmic spraying machine service manual. Felixstowe, England.
3. Pfeiffer, R., R. T. Brunskill, and G. S. Hartley. A variable dosage sprayer for agricultural experiments. Nature 176 : 472. 1955.
4. Wrigley, G. On tour with a logarithmic sprayer. (Automation in testing). World Crops 9, No. 8. 1957.

CONTROL OF ROOT MAGGOTS IN RUTABAGAS IN PRINCE EDWARD ISLAND[1]

D. C. READ AND F. M. CANNON[2]

Canada Department of Agriculture, Charlottetown, Prince Edward Island

[Received for publication March 20, 1958]

ABSTRACT

In 81 tests in 21 localities, from 1952 to 1955, whole-field applications of DDT sprays against adults of root maggots attacking rutabagas, chiefly *Hylemya brassicae* (Bouché), generally gave 50 to 90 per cent fewer infested plants than in untreated fields nearby. The sprays, each at 1 lb. of toxicant per acre, were applied at weekly intervals while flies emerged from overwintered puparia, the period varying with soil type. In eight plot experiments in 1955, a pre-planting treatment with heptachlor at 5 lb. per acre in a 5-inch band, 1½ inches below the seed in the planting ridge, gave an average of 93 per cent control; a similar treatment with aldrin, 80 per cent. Furrow applications at 5 and 2.5 lb. at the same depth were less effective. Post-thinning sprays applied to the crowns of the plants and surrounding soil surface were ineffective. None of the treatments was phytotoxic.

INTRODUCTION

Within the past 10 years, the cabbage maggot, *Hylemya brassicae* (Bouché), has become the major factor limiting the commercial production of table-grade rutabagas in Prince Edward Island. Other species of root maggots are often found in association with it but do not cause economic damage (6).

Studies on the biology and control of root maggots in rutabagas were begun in Prince Edward Island in 1938. Many insecticides were tested from 1938 to 1950 as foliage sprays and soil treatments but none gave adequate protection.

Greenhouse tests showed that DDT readily killed *H. brassicae* flies, suggesting that applications to the foliage of rutabagas should destroy them in the field. Field surveys on the life-history and habits of *H. brassicae* indicated that the time of first attack by the maggots varied as much as 7 weeks in different areas of the Province, and that the period of attack by maggots of the first generation was about 6 weeks in all areas (6). Also, preliminary tests with DDT sprays in 1951 indicated that foliage sprays controlled maggot infestations if applied at the proper time. Field trials, from 1952 to 1955, of properly timed applications to test the treatment are reported herein.

King and Forbes (3, 5) reported excellent results in British Columbia with aldrin and heptachlor applied as pre-planting soil treatments or as sprays to the plant crowns and adjacent soil surface. However, since rutabagas are planted near ground level in British Columbia and in ridges 4 to 7 inches high in Prince Edward Island, the application methods needed to be modified to obtain similar effectiveness in Prince Edward Island. The band and spray applications that were so effective in British Columbia also gave good control on level plantings in Prince Edward Island but they were ineffective on ridged plantings. The present report includes results of tests with pre-planting soil treatments and spray treatments applied to the plant crowns and adjacent soil surface in 1955.

[1] Contribution No. 3772, Entomology Division, Science Service, Department of Agriculture, Ottawa, Ont.
[2] Assistant Entomologist and Officer-in-Charge.

The Laurentian variety of rutabagas (swede turnips) was used throughout.

METHODS

Whole-field Tests

DDT sprays, applied to the foliage to destroy *H. brassicae* flies before eggs were laid, were tested with the co-operation of growers in 21 areas of the Province. Entire fields were treated, and the treatment was evaluated by comparing the percentage of infested plants in each treated field with the average infestation in two to five untreated fields within 200 yards. Standard potato-spraying equipment was used. Weekly applications of 1 lb. of DDT per acre were made during the period of emergence of flies of the overwintered generation, beginning when *H. brassicae* eggs were first found in the fields. At harvest, 20 plants taken from each of five points selected at random in each field were examined and recorded as either clean or injured.

Plot Tests

Aldrin, DDT, and heptachlor were tested in plot experiments on both early- and late-planted rutabagas in each of four localities differing in soil type. Plots were arranged along the side of each field nearest the source of infestation to minimize the variation in exposure to infestation between and within blocks.

Formulations, rates, methods, and numbers of applications of the insecticides are given in Tables 2 and 3. At Mt. Stewart, Augustine Cove, and Earnscliffe, there were four randomized blocks in each experiment, each block having 10 treatments and two untreated check-plots. A plot consisted of four rows, each 30 feet long. At Cherry Valley, there were three randomized blocks, each block having 10 treatments and two untreated check-plots, and each plot having two rows 100 feet long. The rows were $2\frac{1}{2}$ feet apart and the plots 3 feet apart.

The insecticides used in the pre-planting soil treatments were applied with a hand apparatus (Figure 1) that placed the insecticides uniformly in either a 5-inch or a 1-inch band. A flat-topped ridge about 2 inches above ground level was made with a horseshoe or a disk hiller and levelled off with a roller. The band applications were made on this flat surface, and the hilling operation was repeated to enlarge the ridge and place soil over the insecticide. The drill was rolled again so that about 2 inches of soil remained over the insecticide. The rutabaga seed was then sown about $\frac{1}{2}$ inch below the surface of the ridge. When the rutabagas were being thinned to 6 inches apart, the surface of the ridge was removed and about $\frac{1}{2}$ inch of soil was left over the insecticide.

The spray treatments were applied at 40-lb. pressure with a hand-pump sprayer fitted with two nozzles pointing inward and downward, and the spray was concentrated in an 8- to 10-inch band that covered the crowns and leaf stems of the plants and the top and sides of the ridge.

Records of injury in all of the experiments were taken during the last 2 weeks of October. In the sandy and sandy loam areas, where at least two generations of root maggots cause severe injury to rutabagas each year (6), records were also taken in August, after the first-generation attack

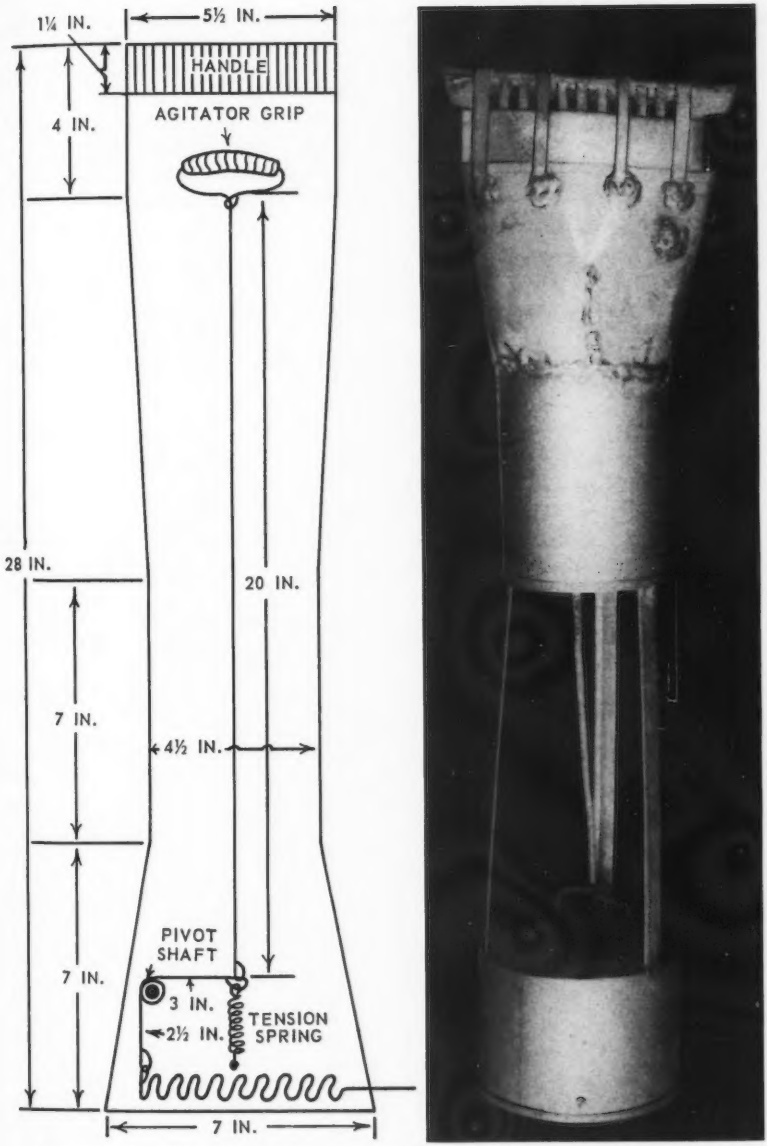

FIGURE 1. Hand-operated applicator used to apply insecticides as wettable powders in 5-inch and 1-inch bands, with a diagrammatic drawing to show construction details.

Applicator is constructed of light-gauge galvanized iron. The lower portion is pressed into the shape of a wedge; 10 openings, 1" × ¼" and ¼" apart, are made on one side, and bottom is then soldered together. A slide, fitted as shown in photograph, moves up or down over the openings to control rate of flow of the insecticide. Agitator, shown in diagram, is made of No. 9 wire, and the pivot rod is a ¼" rod of iron that passes through, and is soldered to, the sides of the applicator; as the agitator grip is moved upward manually and the tension spring pulls downward the wire at the bottom moves from side to side and maintains an even flow of insecticide through the openings. The lower end of the tension spring is soldered to the side of the applicator about 1" from bottom. (About 3 hours' labour is required to construct this device, and materials cost about $3.00.)

had ended. Fifty plants taken at random in each plot were examined at Cherry Valley and 25 plants per plot at Mt. Stewart, Augustine Cove, and Earnscliffe. Appraisal of control was based on the number of larval tunnels in each plant examined, since this method gave more detailed information under local conditions than that of King and Forbes (4). However, the damage index by King and Forbes is given in Table 3 for comparison.

To determine if the treatments were phytotoxic, 80 plants per treatment, taken at random from the early-planted plots during late July and early August, were measured for greatest root diameter. Because of the labour involved in cleaning and trimming, no attempt was made to take weight measurements.

All results were tested for significance by an analysis of variance.

RESULTS

Whole-field Tests

Table 1 shows the results of the whole-field trials with foliage sprays of DDT. Any measure above 50 per cent was considered satisfactory control, and in the localities where five or more applications were made good control was obtained and farmers were well satisfied with the results. Figure 2 shows that good control was obtained when the applications of the

TABLE 1.—CONTROL OF ROOT MAGGOTS IN INDIVIDUAL RUTABAGA FIELDS AFFORDED BY WHOLE-FIELD APPLICATIONS OF FOLIAGE SPRAYS OF DDT[1] IN VARIOUS AREAS OF PRINCE EDWARD ISLAND ACCORDING TO TYPE OF SOIL, 1952 TO 1955

Locality	Soil type[2]	No. of applications[3]	Control, %[4]			
			1952	1953	1954	1955
Carleton	S	4	85	75	—	—
Mt. Stewart	S	6	60	50	10	65
Tryon 1	SL	3	40	40	20	45
Tryon 2	SL	5	45	60	35	65
Augustine Cove	SL	5	70	60	30	70
Hampton	SL	4	70	55	15	65
New Haven	SL	9	90	95	95	95
Clyde River	SL	7	80	60	60	80
Mt. Herbert	L	6	70	85	45	75
Hazelbrook	L	4	50	50	20	—
Pownal 1	L	6	90	60	45	85
Pownal 2	L	4	80	70	—	60
Pownal 3	L	4	70	70	40	65
Vernon Bridge	L	6	75	—	65	80
Waterside	CL	5	70	—	45	70
Mt. Albion	CL	5	80	70	50	75
Cherry Valley	CL	5	85	70	55	70
China Point	CL	4	70	70	40	—
Earnscliffe	CL	4	—	60	45	—
Seal River	CL	6	80	75	60	85
Vernon River	CL	5	70	60	55	75

[1] Para-pará isomer of 1,1,1-trichloro-2,2-bis (*p*-chlorophenyl) ethane; Niatox, 50 per cent wettable powder, Niagara Brand Spray Co., Ltd., Burlington, Ont.
[2] S, sandy; SL, sandy loam; L, loam; CL, clay loam.
[3] Each at 1 lb. of toxicant per acre at weekly intervals while flies emerged from overwintered puparia, or more frequently during wet weather.
[4] Percentage fewer plants injured than in 2 to 5 untreated fields within 100 to 200 yards. Treated and check crops in each area were planted at approximately the same time.

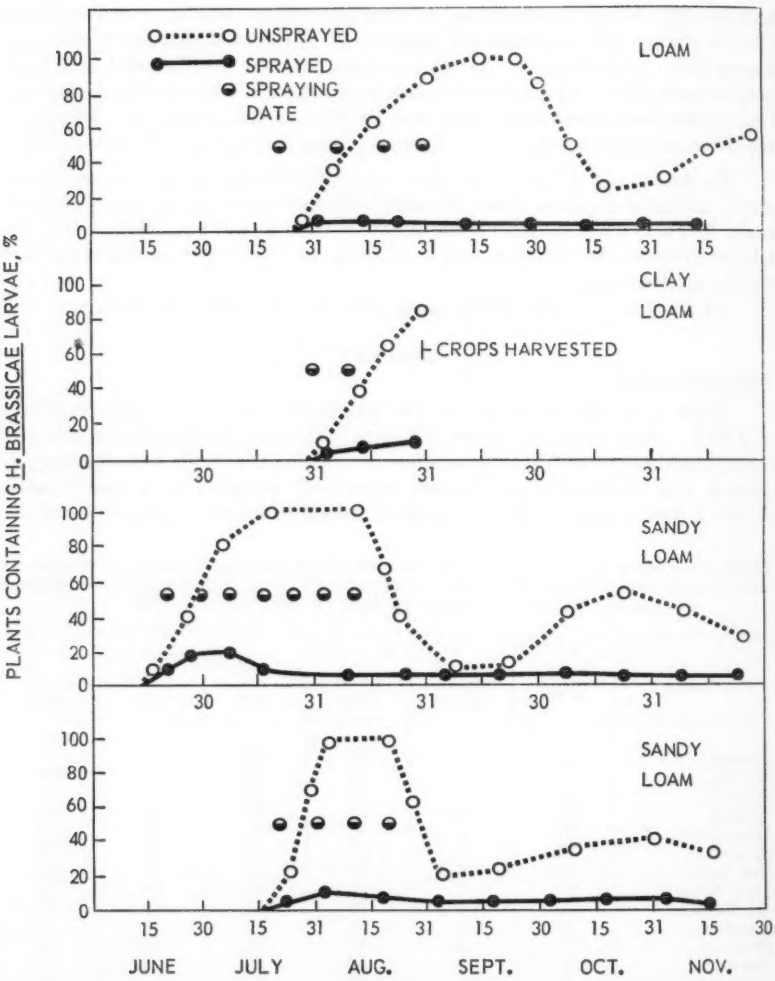

FIGURE 2. Control of root maggots afforded during the season by whole-field applications of DDT sprays to foliage in representative fields of different soil types in Prince Edward Island, 1952. Crops sown: loam soil, about June 16; clay loam, May 12; sandy loam, May 4 and June 28.

Each solid line represents the infestation in a sprayed field and each dotted line the average infestation in 2 to 5 unsprayed fields within 100 yards.

insecticide were made at the proper time in relation to the time of attack by the root maggots in different soil areas. Similar results were obtained in 1953 and 1955. In 1954, with an exceptionally wet growing season, control was lower than for the other years (Table 1), but reduction in injury was generally sufficient to allow a large percentage of the crop to be marketed.

TABLE 2.—CONTROL[1] OF ROOT MAGGOTS FROM TWO TYPES OF BAND APPLICATIONS TO THE SOIL IN EARLY- AND LATE-PLANTED PLOTS OF RUTABAGAS IN FOUR LOCALITIES OF PRINCE EDWARD ISLAND DIFFERING IN SOIL TYPE, 1955

Insecticide[2]	Width of band, in.	Toxicant lb./acre	Sandy Mt. Stewart		Sandy loam Augustine Cove		Loam Cherry Valley		Clay loam Earnscliffe	
			June 6	June 28	May 27	July 12	June 8	June 29	June 14	June 30
Pre-planting Treatments[3]										
Heptachlor	5	5	88	95	84	94	91	99	98	93
Aldrin	5	5	62	83	82	77	67	93	92	74
Heptachlor	1	5	58	82	87	85	82	89	73	87
Heptachlor[4]	1	5	39	75	89	81	86	85	67	66
Aldrin	1	5	49	66	62	43	49	86	67	81
Heptachlor	1	2.5	57	77	73	58	—	—	63	51
Aldrin	1	2.5	26	68	60	57	—	—	65	51
Post-thinning Spray Treatments[5]										
Heptachlor	8–10	3	−15	61	−4	20	—	—	39	48
Aldrin	8–10	7	−8	34	−10	−2	—	—	33	27
Difference necessary for significance at 1% level			36	27	27	46	58	57	40	43
at 5% level			27	20	19	34	47	41	30	31

[1] Percentage fewer larval tunnels in treated than in check plots, on basis of 100 plants per treatment.
[2] Aldrin, 1,2,3,4,10,10-hexachloro-1,4,4a,5,8,8a-hexahydro-1,4,-*endo*, *exo*-5,8-dimethanonaphthalene, 20 per cent wettable powder, obtained from Niagara Brand Spray Co., Ltd., Burlington, Ont.; heptachlor, 1 (or 3a), 4,5,6,7,8,8-heptachloro-3a, 4,7,7,7a-tetrahydro-4, 7-methanoindene, 25 per cent wettable powder and 25 per cent granulated from Velsicol Chemical Corp., Chicago, Ill.
[3] Applied about 1½ inches below the rutabaga seed in ridges 4 to 6 inches high.
[4] Granulated. All other materials were wettable powders.
[5] Three applications: first two at 3- to 4-week intervals while flies of the overwintered generation were present, and third when first-generation flies appeared in experimental areas.

Plot Tests

Table 2 shows the percentage control of root maggot injury for the eight plot experiments, and Table 3 shows the infestation and injury after various insecticide treatments for three of the experiments conducted in 1955. Any measure above 70 per cent was considered good commercial control. In the sandy and sandy loam soils, the pre-planting soil treatments applied in May or early June controlled second-generation larvae in August and September. As the control results in July and August were not significantly different from those in October, only the results of the October examinations are reported.

Except for the 1-inch band treatment of aldrin and the application of granulated heptachlor at 5 lb., all of the pre-planting soil treatments in the eight experiments gave highly significant control. However, the 5-inch band application of heptachlor gave consistently better results than all other treatments.

The spray treatments tested in the plot experiments did not effect significant control. In some of the experiments slight control was indicated, whereas in others infestations were higher in the treated than in the check plots (Table 2). In the loam soil at Cherry Valley, the supplemental sprays increased the control percentages by 4 to 12 per cent; but this increase in protection to the rutabagas was not significant.

TABLE 3.—NUMBERS OF LARVAL TUNNELS PER 100 RUTABAGAS, AND DAMAGE INDEXES, AFTER VARIOUS SOIL TREATMENTS WITH HEPTACHLOR, ALDRIN, AND DDT IN SANDY LOAM, LOAM, AND CLAY LOAM SOILS IN PRINCE EDWARD ISLAND, 1955[1]

Insecticide	Toxicant lb./acre	Larval tunnels[2]			Damage index[3]		
		Sandy loam	Loam	Clay loam	Sandy loam	Loam	Clay loam
Untreated	—	1122	396	284	94	49	44
5-inch band treatment							
Aldrin	5	199(82)	131(67)	24(92)	29	15	4
Heptachlor	5	177(84)	37(91)	7(98)	24	5	1
1-inch band treatment							
Aldrin	2½	452(60)	—	99(65)	46	—	15
Aldrin	5	423(62)	203(49)	93(67)	42	23	14
Heptachlor	2½	299(73)	—	105(63)	33	—	16
Heptachlor	5	145(87)	73(82)	77(73)	15	9	12
Heptachlor[4]	5	119(89)	57(86)	95(67)	12	8	16
Spray treatment							
Aldrin	7½	1008(10)	—	191(33)	84	—	35
Heptachlor	3	1167(−4)	—	173(39)	96	—	28
DDT	6	1239(−10)	—	193(32)	97	—	29
Difference necessary for significance at 1% level		306	231	115			
at 5% level		228	187	86			

[1] For pre-planting band treatments, one application was made at a depth of 1½ inches below the seed in seeding ridges. For the spray treatments, applications (three each of aldrin and heptachlor and six of DDT) were made during the flight period of flies from the overwintered generation of *H. brassicae*. Rutabagas were planted in the sandy loam soil at Augustine Cove on May 27, in the loam soil at Cherry Valley on June 8, and in the clay loam soil at Earnscliffe on June 14.

[2] Figures in parentheses are percentages of control.

[3] After King and Forbes (4).

[4] Granulated. All other materials were wettable powders.

The measurements of the roots in August showed that none of the pre-planting soil treatments was phytotoxic. Comparison of the plants from the treated and untreated plots showed that the early development of the plants in the treated plots was actually increased by 7 to 23 per cent.

DISCUSSION

Although band and the spray treatments of aldrin or heptachlor applied on the surface or in the upper inch of soil in plot tests were effective in controlling root maggot injury in ground-level plantings in Prince Edward Island and in British Columbia (1, 5), they were ineffective on ridged plantings in Prince Edward Island because the surface of the ridges was removed during cultivation and thinning. However, when placed 1½ inches below the seed in the ridge, the insecticides were not disturbed by cultivation and they remained effective during the whole growing season. With the latter method of application, heptachlor at 5 lb. in a 5-inch band gave sufficient protection to warrant recommendations for root maggot control in both early- and late-planted rutabagas in either sandy or clay loam soils. Good control was also obtained with aldrin in most of the tests.

The hand applicator (Figure 1) provides a cheap and simple method of applying the pre-planting soil treatments to small acreages of rutabagas. This device was used by many farmers throughout Prince Edward Island in 1956 and 1957, and in more than 60 fields examined almost complete control of root maggots was obtained.

Since the pre-planting soil treatments have proved so effective and easy to apply, the DDT foliage sprays are no longer being recommended. Although the whole-field sprays were highly effective, variation in the time of attack by the first generation in the different soil areas made it difficult to determine when the first sprays should be applied. Also, during wet weather foliage applications had to be made more frequently and it was not always possible for farmers to follow closely the recommended spray schedule.

REFERENCES

1. Forbes, A. R., and K. M. King. Practical application of chemical controls of root maggots in rutabagas. J. Econ. Entomol. 49:354-356. 1956.
2. Forbes, A. R., and K. M. King. Control of root maggots in rutabagas, especially in muck soils. J. Econ. Entomol. 50:89-91. 1957.
3. King, K. M., R. Glendenning, and A. R. Forbes. Root maggot control on swede turnips. Rept. British Columbia Agron. Assoc. Conf., p. 72. 1953.
4. King, K. M., and A. R. Forbes. Control of root maggots in rutabagas. J. Econ. Entomol. 47:607-615. 1954.
5. King, K. M., A. R. Forbes, D. G. Finlayson, H. G. Fulton, and A. J. Howitt. Coordinated experiments on chemical control of root maggots in rutabagas in British Columbia and Washington, 1953. J. Econ. Entomol. 48:470-473. 1955.
6. Read, D. C. Factors influencing infestation and injury of rutabagas by root maggots (Diptera:Anthomyiidae) in Prince Edward Island. 1. Field studies. Can. J. Plant Sci. 38:188-198. 1958.
7. Stitt, L. L. Insecticide tests for control of maggots in turnips. J. Econ. Entomol. 46:961-965. 1953.

EFFECTS OF FOLIAGE TREATMENTS WITH GIBBERELLIN ON FORAGE YIELD OF ALFALFA, KENTUCKY BLUEGRASS AND WINTER WHEAT

WILLIAM G. CORNS[1]

University of Alberta, Edmonton, Alberta

[Received for publication March 20, 1958]

ABSTRACT

Foliage of alfalfa and of Kentucky Bluegrass grown indoors, and of Kharkov winter wheat planted in springtime in the field, was treated with gibberellin solution before and/or after harvesting the forage once or twice. Visible elongation of leaves and of stems of the grass and wheat, but not of alfalfa, was induced by the chemical treatments. Treatments with 200 p.p.m. gibberellin had no distinguishable effect on weight of alfalfa. Such treatment of Kentucky Bluegrass, before the first cutting, increased fresh and dry weight at the first cutting, did not affect yield at the second harvest, and slightly increased the final total fresh weight. Corresponding chemical treatment, followed by one cutting at the end of the test, increased the weight of the grass as compared to controls cut either once or twice. Treatment with 200 or 400 p.p.m. chemical after the first cutting also increased the yield of the grass. Gibberellin treatment (36 p.p.m.) of wheat foliage harvested once at the end of the experiment improved the yield as compared to controls.

INTRODUCTION

Widespread interest in the potential practical importance of growth stimulation and other effects of gibberellin compounds applied to plants has been responsible for an increasing amount of research of this nature (2), (3), (4).

The present work originated as a study of the influence of seed treatments with gibberellic acid on growth, development and hardiness of Thatcher spring wheat and of vernalized or unvernalized Kharkov winter wheat in the greenhouse (1). In those experiments the optimum concentration of the chemical caused initial stimulation of elongation of leaves and stems, but reduced tillering, had no appreciable effect on terminal height and did not hasten maturity or increase yield. Any concentration of the chemical, great enough to cause visible stimulation of growth, simultaneously caused some chlorosis and weakness of the wheat plants. Excessive concentrations produced loss of colour and vigour without any increase in height.

The aim of the present work was to determine the effects of various treatments with gibberellin upon the growth and forage yields of crops harvested once or twice before maturity. Alfalfa, Kentucky Bluegrass and spring-planted winter wheat were used in the experiments.

MATERIALS AND METHODS

Alfalfa

Grimm alfalfa was seeded in 8″-diameter pots containing black loam soil, in a greenhouse at Edmonton on July 16, 1957. The experiment

[1] Professor of Crop Ecology, Department of Plant Science, University of Alberta, Edmonton, Alta.

covered a 6½-month period with temperature maintained at approximately 70° F. During the last half of the experiment, the plants received supplementary light of approximately 400 f.c. from 5 p.m. to 2 a.m. daily.

Within the first month after emergence of alfalfa seedlings, they were thinned to three plants per pot in each of the four randomized replicates for the various treatments:

1. Gibberellin solution brushed on upper surface of leaves 10 weeks after planting time. Four ml. of aqueous solution of the potassium salt of gibberellic acid containing 200 p.p.m. acid equivalent and added wetting agent were used for each pot for this purpose. Forage was harvested by clipping at 2 inches above ground level, 7 weeks and, finally, 4 months after treatment.
2. Same as group 1, except harvested only once, 4 months after treatment.
3. The first treatment with gibberellin at the same time as for groups 1 and 2. A second treatment, applied to the stubble and leaves 3 days after the first harvest. Forage removed again at the end of the experiment.
4. Treatment with gibberellin delayed until after the first harvest, 17 weeks from seeding time. Harvested again, approximately 9 weeks later, at the end of the experiment at the same time as for the other groups.
5. Controls, no chemical treatment, (a) harvested twice, (b) harvested once at the end of the experiment. Fresh and dry weights recorded.

Kentucky Bluegrass

This experiment was started under the same conditions as the test with alfalfa. Uniform 5 cc. measures of the grass seed were planted in 8-inch pots of soil in the greenhouse where the plants were exposed to natural illumination and controlled temperature of approximately 70° F. for the duration of the test from July 16 to November 19. Each of the following treatments was done in quadruplicate:

1. Gibberellin applied twice to the foliage before harvesting twice. The foliage in each pot was sprayed on two dates, using an atomizer with 2ml. of 200 p.p.m. gibberellin solution (equivalent to approximately 50 g. acid equivalent per acre). The first of the two equal applications was made one month after seeding-time, the second one week later. Twelve days after the second application of the chemical, fresh and dry weights were recorded for the first harvest. The leaf material was harvested again at the close of the experiment.
2. Same as group 1, but clipped only once, at the end of the test, approximately 3 months after the second chemical treatment.
3. Gibberellin applied to the stubble after the first harvest of previously untreated plants. Four days after the first clipping of these previously unsprayed plants two rates of chemical application were used for two comparable sets of pots. One set 3(a) received 4 ml. of 200 p.p.m. gibberellin solution per pot, sprayed on the newly started regrowth. The other set 3(b) was treated with an equal amount of 400 p.p.m. solution. The yields were recorded at the same time as those for the other groups.
4. Material without chemical treatment, as controls for the other groups.

Winter Wheat

Kharkov winter wheat seed was planted in the field at Edmonton on June 5, 1957, in quadruplicate randomized blocks. Each treatment included 20 plants in two rows of 10 plants, 1 foot apart with 2 feet between rows. Wheat plants in the following groups were sprayed with 2 ml. 36 p.p.m. gibberellin solution per plant to wet the foliage:

1. Treatment July 17, forage harvested one week later and again September 3.
2. Same as for group 1, but harvested only once, September 3.
3. Treatment delayed until 2 days after the first clipping, timed as in 1. Forage harvested again, September 3.
4. Controls, no chemical treatment, (a) harvested twice, (b) harvested once.

FIGURE 1. Kharkov winter wheat in the field, at Edmonton, 6 weeks after seeding in springtime. The plants in the row on the *right* were sprayed with 36 p.p.m. gibberellin, 8 days before the photograph was taken. *Left*—check.

RESULTS

Visible Effects

None of the chemical treatments of alfalfa produced an appreciable visible response in the growing plants.

The first application of gibberellin solution to foliage of Kentucky Bluegrass was without noticeable effect on the elongation or colour of the foliage prior to its second treatment. This second treatment caused approximately 10 per cent increase in height of the treated plants accompanied by very slight yellowing of the leaves prior to the first harvest. The "stubble" treatments with gibberellin caused more noticeable stimulation of growth in height and an incipient chlorosis.

The chemical caused the expected elongation of leaves of winter wheat following treatments of either the intact foliage or the clipped plants. This was associated with somewhat less healthy, narrower leaves and more slender, more upright stems than those of the controls (Figure 1).

Yields

Tables 1, 2 and 3 summarize the data for weights of the different species after the various treatments outlined above. Since they add little to the interpretation of the results, the data for fresh weights of alfalfa and winter wheat are omitted from the respective tables.

DISCUSSION AND CONCLUSIONS

Alfalfa

The data in Table 1 indicate that gibberellin treatment of alfalfa either before, or after, or before and after, the first cutting, had no effect on the yield of forage. Total yields show only a significantly greater weight from a final single clipping than from the combination of two clippings, regardless of chemical treatment of the alfalfa.

TABLE 1.—MEAN YIELDS OF ALFALFA FORAGE PER REPLICATE (4 REPLICATES, 12 PLANTS EACH) FOLLOWING TREATMENT OF PLANTS WITH 200 P.P.M. GIBBERELLIN SOLUTION BEFORE AND/OR AFTER CLIPPING

Treatments	Grams dry weight			% relation to 5(a) or 5(b)
	First clipping	Second clipping	Total	
1. Gibberellin (G.) followed by 2 clippings	11.2	14.2	25.4	97 (5a)
2. G. followed by 1 final clip	—	37.6**	37.6**	105 (5b)
3. G. before and after first clip	10.9	17.4	28.3	108 (5a)
4. G. after first clip	11.9	12.8	24.7	94 (5a)
5. Controls (a) 2 clips	12.0	14.3	26.3	100 (5a)
(b) 1 clip	—	35.8**	35.8**	100 (5b)
L.S.D. at 5% level*	3.53	4.94	6.85	
L.S.D. at 1% level**	4.95	6.76	9.38	

** Significance with respect to 5(a)

TABLE 2.—MEAN YIELDS OF KENTUCKY BLUE GRASS FORAGE AS FRESH WEIGHT AND DRY WEIGHT PER REPLICATE (4 REPLICATES, 4 POTS EACH) FOLLOWING TREATMENT WITH 200 OR 400 P.P.M. GIBBERELLIN SOLUTION BEFORE OR AFTER CLIPPING

Treatment	First clipping		Second clipping		Total		% relation to 4(a) or 4(b)	
	Fresh wt. gm.	Dry wt.	F.W.	D.W.	F.W.	D.W.	F.W.	D.W.
1. Gibberellin (G.) 200 p.p.m. twice followed by 2 clippings	53.6**	12.2**	28.9	10.4	82.5*	22.6	113	113 (4a)
2. G. twice followed by 1 final clip	—	—	84.3**	36.4**	84.3*	36.4**	117	121 (4b)
3. (a) G. 200 p.p.m. after first clip	41.3	9.3	42.3**	14.9*	83.6*	24.2*	114	121 (4a)
(b) G. 400 p.p.m. after first clip	41.7	9.5	44.8**	17.0**	86.5**	26.5**	118	133 (4a)
4. Controls (a) 2 clips	43.0	9.5	30.3	10.5	73.3	20.0	100	100 (4a)
(b) 1 clip	—	—	71.7**	30.0	71.7	30.0**	100	100 (4b)
L.S.D. at 5% level*	5.45	1.90	7.77	3.21	9.10	3.42		
L.S.D. at 1% level**	7.64	2.66	10.65	4.40	12.46	4.69		

* or ** Significance with respect to (4a)

The yield data in association with the lack of any visible response to gibberellin treatments suggest that it is unlikely that a positive response to this chemical would be obtained with alfalfa grown in the field. However the period of slower growth in the fall or early spring would seem to be a very suitable time to investigate this point.

Kentucky Bluegrass

Table 2 shows an expected superiority in the yield of untreated grass harvested once at the end of the test, as compared to the total harvest from two clippings during the same period.

Chemical treatment, followed by one cutting at the end of the experiment, increased the yield as compared to that of controls and produced the greatest amount of dry matter for the whole test.

Gibberellin treatment before the first cutting improved its yield at the first cutting but did not affect weight at the second cutting. This is evidence of the subsiding nature of the stimulation of growth by gibberellin.

Chemical treatment after the first clipping also improved the yield of the grass, apparently to a somewhat greater extent than did the earlier treatments of comparable material harvested twice.

Reference has been made to the somewhat less vigorous appearance of the treated material. The question of the potential value of supplemental fertilization seems pertinent in this connection. However, to the writer's knowledge, there is no evidence that supplementary fertilizer treatments can in practice compensate completely for gibberellin-induced loss of vigour of grass species. The work of Leben and Barton (2) indicated that applications of fertilizer, even at rather high rates, were incapable of preventing eventual chlorosis of Kentucky Bluegrass treated with gibberellin in the fall. The dry weight of such material, however, was slightly higher than it was when fertilizer was used without the gibberellin treatment. As the authors point out, these matters merit further attention over a longer period.

TABLE 3.—MEAN YIELDS OF KHARKOV WINTER WHEAT FORAGE PER REPLICATE (4 REPLICATES, 20 PLANTS EACH) FOLLOWING TREATMENT WITH 36 P.P.M. GIBBERELLIN SOLUTION BEFORE OR AFTER CLIPPING

Treatment	Kg. dry weight			% relation to 4(a) or 4(b)
	First clipping	Second clipping	Total	
1. Gibberellin (G.) followed by 2 clippings	.136	0.473	0.609	92 (4a)
2. G. followed by 1 final clip	—	1.305	1.305**	119 (4b)
3. G. after first clip	.123	0.561	0.684	104 (4a)
4. Controls				
(a) 2 clips	.132	0.525	0.657	100 (4a)
(b) 1 clip	—	1.097	1.097**	100 (4b)
L.S.D. at 5% level	0.023	0.111	0.094	
L.S.D. at 1 % level	0.032	0.153	0.127	

* or ** Significance with respect to (4a)

Winter Wheat

Gibberellin treatment increased the weight of wheat forage harvested once at the end of the experiment (Table 3). In this respect the results were comparable to those for Kentucky Bluegrass. Other gibberellin treatments, despite their visible effects on the plants in the field, were without significant effect on the yield.

General

On the whole, the positive results from these studies are not without encouragement for further research concerning the timing of the chemical applications with respect to stages of growth, dates of harvest, fertilization, and quality of the produce. Longer term effects with perennial species should be of interest. There appears, however, to be little basis for unreserved enthusiasm about immediate prospects for practical agricultural use of gibberellin in this way.

ACKNOWLEDGEMENTS

Financial assistance has been given by the Dominion Department of Agriculture, the National Research Council and the University of Alberta. The technical assistance of Raymond Schraa is also gratefully acknowledged. Merck & Co., Ltd., kindly provided some of the gibberellin used in this project.

REFERENCES

1. Corns, Wm. G. Growth responses of wheat to gibberellin. Proc. Can. Soc. Agron., pp. A62-64. 1957.
2. Leben, C., and L. V. Barton. Effects of gibberellic acid on growth of Kentucky Bluegrass. Science 125 (3246) : 494-495. 1957.
3. Marth, P. C., W. V. Audia, and J. W. Mitchell. Effects of gibberellic acid on growth and development of plants of various genera and species. Botan. Gaz. 118 (2): 106-111. 1956.
4. Stowe, B. B., and T. Yamaki. The history and physiological action of the gibberellins. Ann. Rev. Plant Physiol. 8 : 181-216. 1957.

STUDIES ON THE SIX-SPOTTED LEAFHOPPER, MACROSTELES FASCIFRONS (STÅL.), AND ASTER YELLOWS IN MANITOBA

P. E. Lee and A. G. Robinson[1]

University of Manitoba, Winnipeg, Manitoba

[Received for publication February 10, 1958]

ABSTRACT

Evidence from nymphal and adult counts suggested that adult *Macrosteles fascifrons* (Stål.) migrate from the south into Manitoba each year, and produce one generation before autumn. Lettuce was shown to be the preferred host over aster, parsley, carrot and flax. Cage experiments showed that head lettuce free from aster yellows virus can be produced when the insect vectors are excluded. Eight varieties of head lettuce were tested for resistance to the disease. Only one variety, Trianon Cos, showed any degree of tolerance. Transmission tests from celery and zinnia indicated the presence in Manitoba of the western strain of the virus.

INTRODUCTION

The six-spotted leafhopper, *Macrosteles fascifrons* (Stål.), is the only known vector in Manitoba of the virus disease, aster yellows, *Chlorogenus callistephi* H. No effort has yet been made to find other vectors. Since about 1950 this insect has been present in very large numbers, and there has been a corresponding high incidence of aster yellows in commercial crops of flax, sunflowers, lettuce, carrots, celery and others, as well as many ornamental plants. Before 1950 there were occasional reports of aster yellows on carrots. Since then growers estimate losses on head lettuce varying from 10 to 100 per cent. Average loss in flax for Manitoba in 1957 is estimated by the Plant Pathology Laboratory, Winnipeg, as 15 per cent.

Because of complete lack of any knowledge locally on the biology of the insect vector, the virus, or vector-virus relationships, a study was initiated in the spring of 1955, and continued during 1956 and 1957. The main results obtained will be presented under the following headings: (1) biology of the insect; (2) host preference of the insect; (3) demonstration and confirmation of aster yellows symptoms on head lettuce; (4) tests for resistance or tolerance in eight varieties of head lettuce; (5) determination of strains of aster yellows.

BIOLOGY OF THE INSECT

The most puzzling problem in the life history of the six-spotted leafhopper in Manitoba is the source of the infestations. A few adults were collected by sweeping grasses and weeds on the following earliest dates: May 21, 1954; May 6, 1955; May 18, 1956; and May 29, 1957. These could be overwintered adults or early migrants from the south. In 1957 a check on sex ratio showed all adults collected early in the season to be females. However, large numbers of adults were not found before June

[1] Research Assistant and Associate Professor, respectively, Department of Entomology, University of Manitoba, Winnipeg, Man.

FIGURE 1. Nymphal and adult populations of the six-spotted leafhopper, *Macrosteles fascifrons* (Stål.), on five plant hosts, 1955 and 1956.

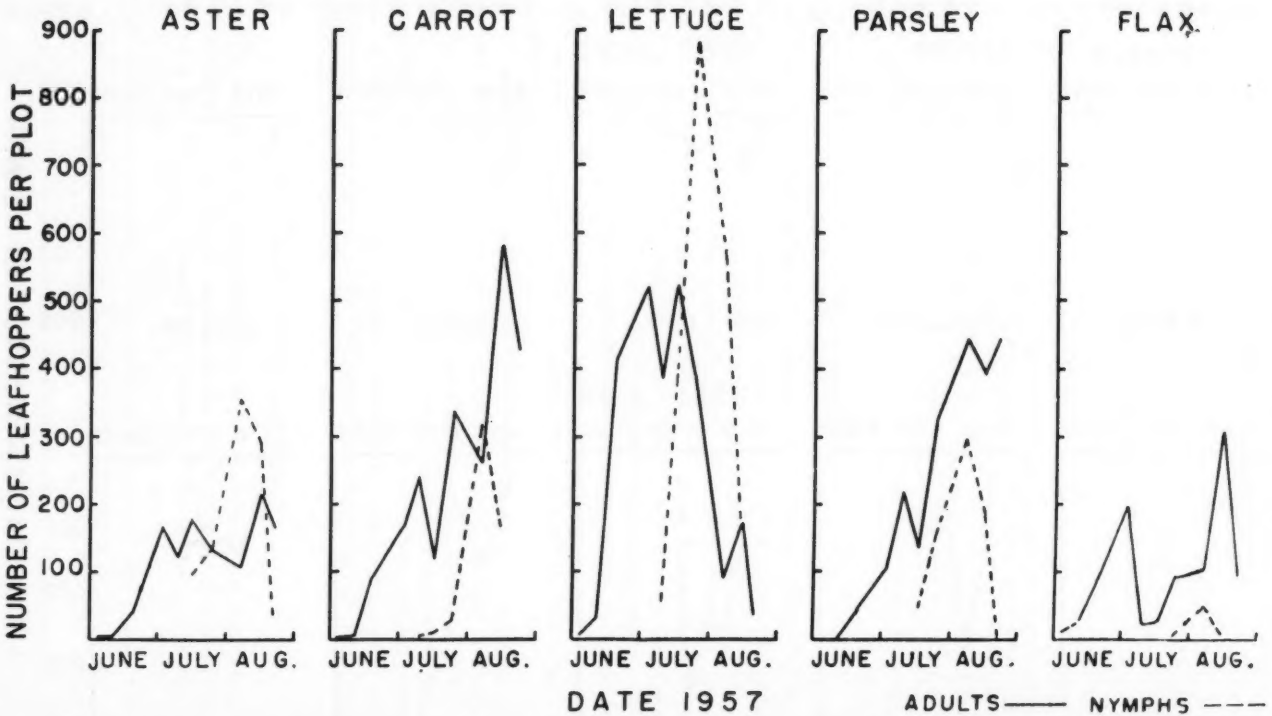

FIGURE 2. Nymphal and adult populations of the six-spotted leafhopper, *Macrosteles fascifrons* (Stål.), on five plant hosts, 1957.

15 or later in any year. If there is overwintering in the adult stage it must be in very small numbers, unless most of the adults have a long diapause. If the insect overwinters in the egg stage, nymphs should be found before adults; but no nymphs are found until adults have been present in large numbers for 3-4 weeks (Figures 1 and 2). The sudden increase in numbers of adults, shown in Figure 1, lettuce, July 1955, and in Figure 2, lettuce, June 1957, indicates a migration from the south. This is supported by meteorological data showing that between July 11-13, 1955, there were southerly winds for a duration of 48 hours, varying from 6-32 m.p.h. with an average on July 12 of 22.5 m.p.h.; on July 16, 1955, southerly winds for a duration of 16 hours, varying from 7-12 m.p.h. with an average of 9.1 m.p.h.; and from July 18-21, 1955, southerly winds for a duration of 86 hours, varying from 5-26 m.p.h. with an average of 15.7 m.p.h. on July 19. In 1957, there were southerly winds on June 12 for 19 hours, varying from 5-21 m.p.h. with an average of 14.7 m.p.h.; and on June 19 southerly winds for 17 hours, varying from 5-21 m.p.h. with an average of 12.3 m.p.h. In 1956 (Figure 1), populations were lower all season than in 1955 or 1957.

The number of generations per year is not definitely known. Ikumogunniyi (3), from adults collected on May 21, 1954, at Winnipeg, Manitoba, successfully reared two complete generations of the leafhopper in an unheated laboratory room with no artificial light. Under these conditions the insect developed from egg to adult in 28 days. However, the data on lettuce (Figures 1 and 2) indicate only one generation per year. Nymphal counts for 1957 on all five hosts show one generation (Figure 2).

HOST PREFERENCE

Studies on the host preference of the insect for aster, carrot, lettuce, parsley and flax were conducted in randomized, replicated field plots. In 1955, each host plant was replicated in rows six times; in 1956 three times; and in 1957 four times. Rows were 15 feet long. Guard rows, on which counts were not made, were planted next to each row in the two latter years of the study. With the exception of some transplanting of asters in 1955, due to poor germination, all plots were hand-seeded, and thinned after germination to allow optimum growth.

Three random sample counts for both nymphs and adults were made per row. For lettuce, one head was used for one sample count, and for the other four hosts one foot of row. The plants were gently disturbed with the hand, and quick counts made of adults in the air, on the foliage and on the soil, or of nymphs on the foliage and on the soil. Exact numbers, of course, were not obtained, particularly with high numbers; but all counts were made by one person, and show population differences among plants, among weeks, and among years (Figures 1 and 2). Counts were made as nearly as possible at weekly intervals, commencing each year when plants were in the seedling stage.

Feeding preferences are indicated from total adult counts (Figures 1 and 2). Flax was the least preferred of the five hosts, but the differences among the others were small. The late season preference for feeding on

flax (Figure 2) is explained by the characteristic late tillering of flax when other hosts are less succulent or otherwise unattractive to the insect. If it is taken into account that lettuce matures earlier than parsley or carrot, then lettuce is the most attractive host (Figures 1 and 2).

Because the nymphs tend to feed on the plants where they were hatched, particularly in early instars, total nymphal counts (Figures 1 and 2) show host preferences for oviposition. Lettuce is very much the preferred host for oviposition followed in descending order of preference by aster, parsley, carrot, flax. Figures 1 and 2 show the preference for lettuce, particularly in 1955 and 1956 when nymphal counts in most cases were too low on the other hosts to show when graphed.

ASTER YELLOWS INJURY ON LETTUCE AND ITS RELATION TO LEAFHOPPERS

In 1955 and 1956 there was always some doubt concerning symptoms of aster yellows on diseased plants. Grogan *et al.* (2) have described several diseases of lettuce, including aster yellows. The symptoms of some diseases are similar to those of aster yellows, particularly to anyone not familiar with lettuce diseases. An attempt was made in 1957 to verify that heavy losses by market-gardeners were due to aster yellows, and to learn to distinguish definitely the symptoms of this disease.

Cages were constructed of saran screen (32 mesh)* mounted on an iron frame, 15 feet long, 18 inches wide, and 1 foot high (Figure 5). Thirty rows (23 on June 14 and 7 on June 19) of head lettuce (Pennlake) transplants were planted in rows 15 feet long and 4 feet apart. Transplants were obtained from seeded rows in the field, and cages excluded leafhoppers on all plants to the dates of transplanting.

The 30 rows were randomized as follows: 10 rows each covered with a cage to exclude leafhoppers; 10 rows each covered with a cage into which leafhoppers were introduced; 10 rows left uncovered. Each of the 10 rows covered to exclude leafhoppers was sprayed with malathion to kill any adults which might have alighted on the plants during the short time of exposure during transplanting. Adult leafhoppers were collected by sweeping lettuce and carrot in vegetable plots, and introduced into 10 cages between June 19 and July 2. By the latter date more than 100 adults had been placed in each cage.

All the 10 rows in which cages excluded leafhoppers produced healthy marketable heads of lettuce (Figure 3). The other 20 rows produced no marketable heads and all plants showed symptoms of aster yellows, chlorosis, stunting of new growth, lack of head formation and typical pinkish latex exudation (Figure 4). The results established conclusively that the lettuce developed normally when protected from leafhopper feeding and, conversely, that plants exposed either artificially or naturally to leafhopper feeding were infected with aster yellows.

RESISTANCE OF LETTUCE VARIETIES TO ASTER YELLOWS

Because of failures to protect lettuce from leafhopper feeding by the use of insecticides, and the problem of toxic residues remaining on the

* Lumite, from Lumite Division, Chicopee Mills, Inc., New York, N.Y.

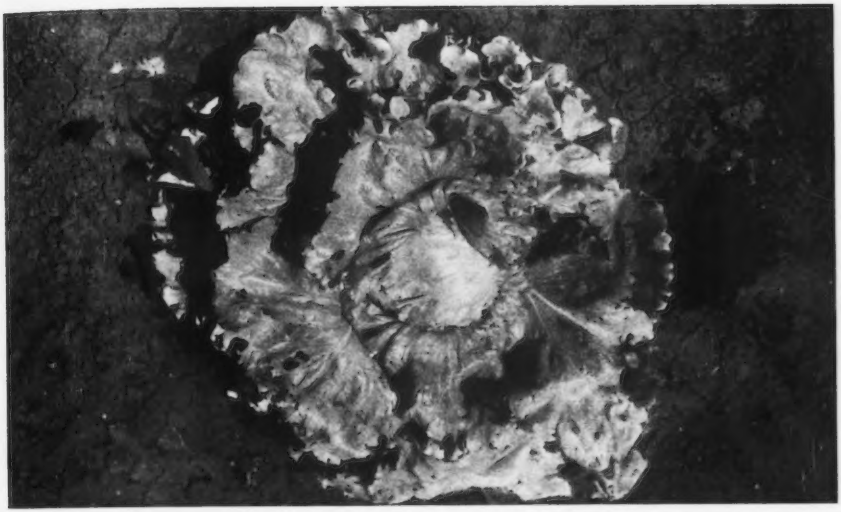

FIGURE 3. Normal development of head lettuce protected by saran-covered cage from leafhopper feeding.

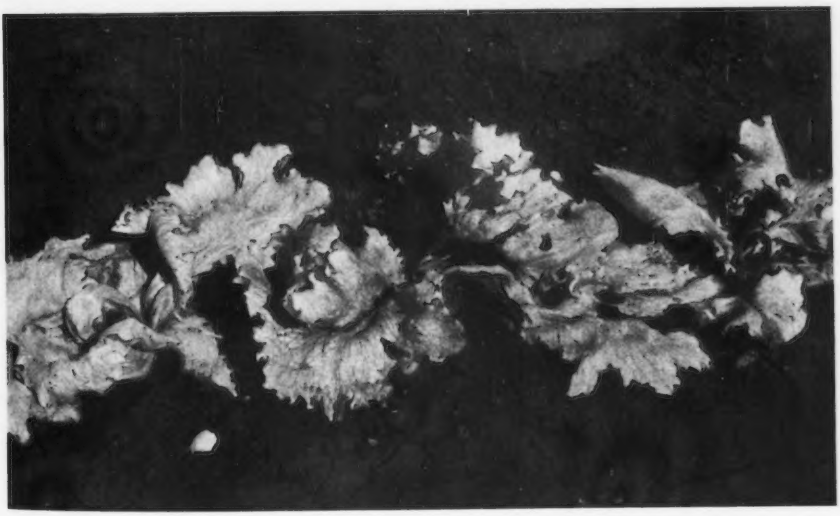

FIGURE 4. Head lettuce exposed to leafhopper feeding showing typical symptoms of aster yellows.

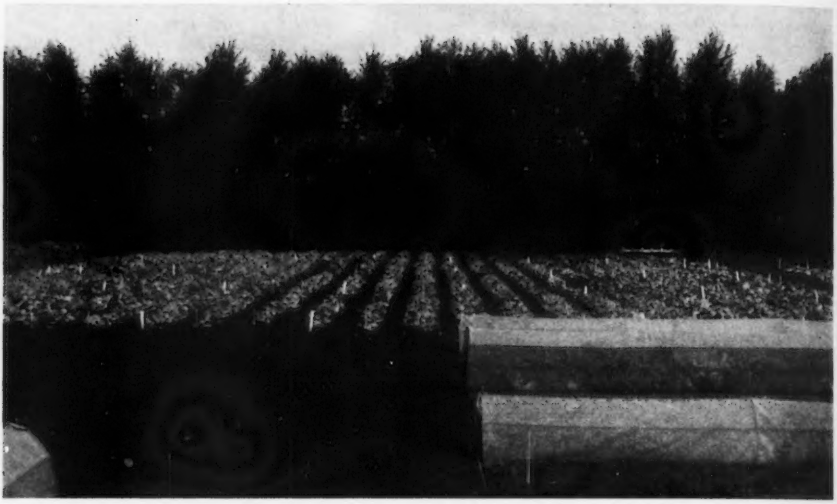

FIGURE 5. Field plots showing early growth stage of lettuce in tests for varietal resistance to aster yellows. Note saran-covered cages in foreground, used to demonstrate that virus-free lettuce can be grown by excluding the vector.

FIGURE 6. Trianon Cos variety of lettuce in foreground infected with aster yellows. Dark areas in background are remains of other varieties in the same test which succumbed very rapidly to the disease.

leaves at harvest time when insecticides are used, the use of resistant varieties may in the future offer a solution. In 1957 eight varieties of lettuce were tested in the vegetable plot at the University of Manitoba. The varieties were: Pennlake, Great Lakes 659, and Imperial 456 (True head types); White Boston and Cobham Green (Butter head types); Salad Bowl and Grand Rapids (Leaf types); Trianon Cos (Cos type).

Each variety was seeded in the field on two dates, "early-seeded" on May 13, and "late-seeded" on June 24. Each variety for each date of seeding was sown in plots of three rows. Each row was 2 feet apart and 15 feet long. Plots were 3 feet apart. Plots for each variety were replicated four times. Observations were made only on the centre row of each plot. Rows were thinned after germination so that plants were about 1 foot apart (Figure 5).

In the early-seeded plots, seedlings were observed on May 24, and the first adult leafhoppers on June 4. By June 16 all varieties showed typical symptoms of aster yellows. The head types died without forming marketable heads. In the late-seeded plots all varieties showed symptoms of aster yellows by July 23, and no marketable lettuce was obtained.

None of the eight varieties showed resistance to aster yellows, in either the early-seeded or late-seeded plots, but there were differences in tolerance as expressed by the length of time they survived. The least tolerance was shown by the butter head varieties, White Boston and Cobham Green, where only one plant in thirty lived long enough to bolt. The most tolerance was shown by the one Cos type, Trianon Cos. Despite the fact that all plants of this variety developed aster yellows, they continued to live much longer (Figure 6) than any other variety, a considerable number of them bolting. The other varieties showed no appreciable tolerance.

IDENTIFICATION OF ASTER YELLOWS STRAIN

The literature on the existence of two strains of the aster yellows virus in North America has been reviewed recently by George and Richardson (1). The two strains are known as the Eastern or New York strain and the Western or California strain. The Eastern strain is said to occur on lettuce, but not on celery, *Apium graveolens* L., or *Zinnia elegans* Jacq., while the Western strain is identified by its occurrence on celery and zinnia. Both strains are transmitted by *Macrosteles fascifrons*, the only vector so far known in Manitoba. George and Richardson (1) presented evidence that the strain found on celery in Ontario is similar to that present in California. A series of tests were made in 1957 at the University of Manitoba to determine the identity of the strain in the Winnipeg area.

Tests with Laboratory-reared Leafhoppers

A non-viruliferous culture of *M. fascifrons* was established by collecting adults in the field, placing them in cages in the laboratory on barley seedlings, and removing them after they had oviposited. The nymphs and adults from these eggs were free of virus, because barley is not infected by aster yellows. Adults were tested on aster to ensure that they were non-viruliferous. The cages were 12 inches by 12 inches by 16 inches of celluloid (cellulose nitrate) sides and saran screen top, covering a wooden frame.

FIGURE 7. Cage used in virus transmission studies (from pattern kindly supplied by K. Maramorosch).

Zinnia plants showing aster yellows symptoms were obtained from the Winnipeg City Park, and from the Entomology Laboratory, Saskatoon, Saskatchewan. Non-viruliferous adult leafhoppers were caged on leaves of infected zinnia in Visking dialyzing tubing (28 mm. diameter), 10 on one plant and 6 on another. After 3 days, the 16 adults (in groups of 5, 5 and 6 individuals) were placed on three virus-free aster plants (4-6 inches tall) in pots, each covered by a celluloid cage 10 inches high, 3.5 inches in diameter, with four 2-inch square windows and the top of the cage made of saran screen (Figure 7).

Symptoms of aster yellows showed on all three aster plants by the 31st day after introduction of the insects. The leafhoppers were then removed, and replaced on the diseased asters by non-viruliferous adults which in turn after feeding were placed on virus-free celery plants. Forty days after introduction of viruliferous leafhoppers the celery showed symptoms of aster yellows. This transmission of the virus from zinnia to aster to celery indicates the presence of the Western strain in material from both Winnipeg and Saskatoon.

Tests with Field-collected Leafhoppers

In another series of virus transmission tests adult leafhoppers were collected by sweeping lettuce plants in the vegetable plot at the University of Manitoba and placed in cages (Figure 7) over virus-free celery, aster, or wild lettuce, *Lactuca canadensis* L. This provided a supply of leafhoppers for the following tests. On June 4, two celery plants were each infested with 12 leafhoppers which were left on the plants for 17 days. Only one of the two plants developed symptoms of aster yellows. On June 10, the same number of insects were placed on two other celery plants, and all leafhoppers died before June 21. In this test both plants became infected with aster yellows. On June 10, two aster plants were infested

in a similar manner, the insects remaining for 16 days. Both plants developed aster yellows. On July 22, one plant of wild lettuce was available, and artificially infested with 20 adult leafhoppers for 8 days, and this plant also became infected with aster yellows. Two observations may be made on these virus transmission tests from field-collected insects. First, the population in the field must have contained a high percentage of viruliferous insects, i.e., at least 1 insect in 12 must have been capable of transmitting the virus. Second, the transmission of the virus from lettuce in the field to celery, in three attempts out of four, indicates that the strain in the Winnipeg area can infect celery, the criterion at present used to identify the Western strain of the virus.

ACKNOWLEDGEMENTS

Grateful acknowledgement is made to the Manitoba Department of Agriculture and Immigration for the generous financial assistance provided for this project; to H. R. Hikida, of the Department of Plant Science, University of Manitoba, for supplying plots and valuable horticultural advice; and to W. W. A. Stewart, of the Entomology Laboratory, Saskatoon, Sask., for supplying plants which were used in transmission studies.

REFERENCES

1. George, J. A., and J. K. Richardson. Aster yellows on celery in Ontario. Can. J. Plant Sci. 37 : 132-135. 1957.
2. Grogan, R. G., W. C. Snyder, and R. Bardin. Diseases of lettuce. Calif. Agr. Expt. Sta. Circ. 448. 1955.
3. Ikumogunniyi, B. A. A study of two horticultural insect pests. Part 1: A study of the life history, habits and control of the six-spotted leafhopper *Macrosteles fascifrons* (Stål.). M.Sc. thesis, Dept. Entomol., Univ. Man., Winnipeg, Man. 1955.

VEGETATION ZONES AND THEIR RELATIONSHIP TO THE SOILS AND CLIMATE OF THE UPPER COLUMBIA VALLEY

ALASTAIR MCLEAN AND W. D. HOLLAND

Canada Department of Agriculture

[Received for publication October 28, 1957]

ABSTRACT

The study reported deals with a description of the climate, vegetation and soils of the Upper Columbia Valley, British Columbia, between the valley floor and about 3500-ft. elevation.

Precipitation appears to be the principal factor governing both soils and vegetation development in the region. Most of the soils in the valley have been derived from highly calcareous parent material. The zonal soils include Dark Brown, Brown Wooded, Gray-Wooded, Brown Podzolic-Gray Wooded, Podzol Gray Wooded and Podzols.

Within the main Columbia Valley there appears to be a good parallel relationship between soils and vegetation, at least at the great soil group level. The same relationships that exist in the main valley do not appear to hold, however, in the tributary valleys to the west where the soil parent material is less calcareous.

The vegetation of the region has been broken down into three major vegetation zones, namely, Douglas-fir, cedar/hemlock, and spruce/fir. The Douglas-fir zone was divided into two sub-zones, groveland and forest.

INTRODUCTION

The study reported herein deals with a description of the climate, soils and vegetation of the Upper Columbia Valley. This valley forms part of the Rocky Mountain Trench, a physiographically unique land feature which cuts through the eastern part of British Columbia in a northwest-southeast direction. Specifically, the study area is that covered by the British Columbia Soil Survey, from Canal Flats to Bluewater Creek about 140 miles to the north, and from the valley floor (2600 feet) to approximately 3500 feet (Figure 1).

The valley is bounded on the east by the van Horne, Brisco, and Stanford Ranges of the Rocky Mountains. The eastern series of ranges reach as high as 9000 feet with bare, rugged peaks and deeply dissected valleys. Only three notable breaks occur in these ranges, namely, Sinclair Pass, the trench of the Kicking Horse River which meets the Columbia River at Golden, and that of the Blaeberry River.

On the west side of the valley, the Dogtooth Mountains, the eastern range of the Purcells between Spillimacheen and Beavermouth, appear as an intra-valley ridge and narrow the Trench to about 4 miles in width at Parson, whereas at Spillimacheen it is about 8 miles wide. The only major gap is that of the Spillimacheen Valley.

The foothills are very narrow or lacking over most of the area and, since the valley floor is generally narrow, the Trench has the appearance of being long and deep, with precipitous sides rising sharply to the summits of the adjacent mountain ranges.

[1] Ecologist, Range Experimental Farm, Canada Department of Agriculture, Kamloops, B.C.
[2] Soil Surveyor, Soil Survey Branch, British Columbia Department of Agriculture, Kelowna, B.C.

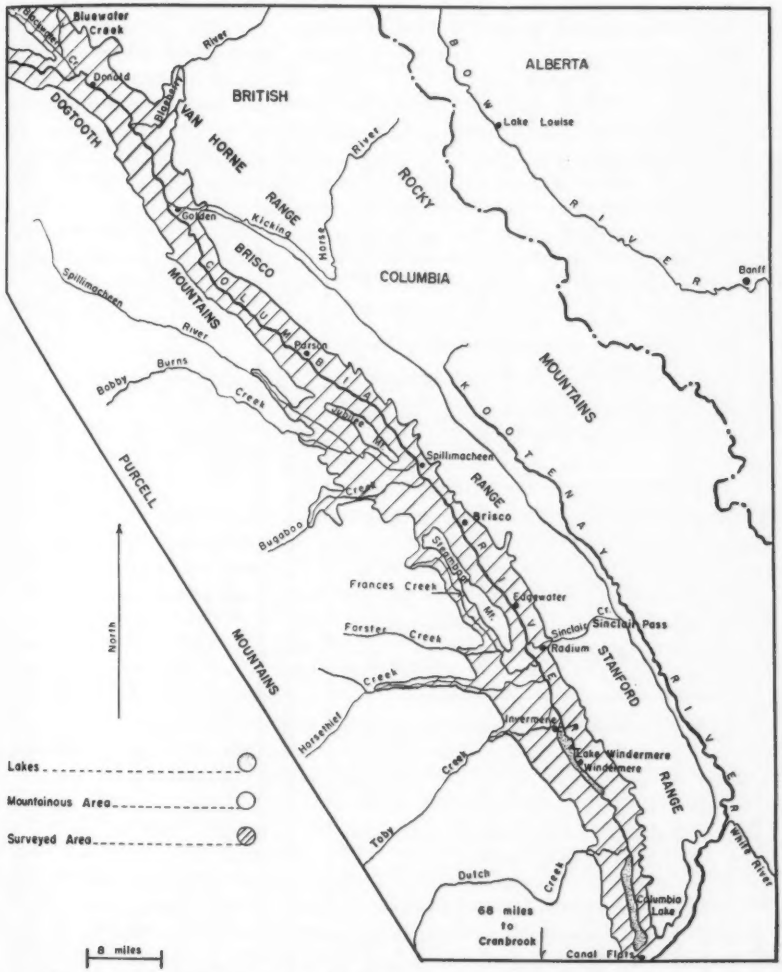

FIGURE 1. Map of the Rocky Mountain Trench between Canal Flats and Bluewater Creek.

A soil survey was carried out in the Upper Columbia region from 1950 to 1954 by the Soil Survey Branch of the British Columbia Department of Agriculture, as part of their investigation of the Columbia River drainage basin. An ecological survey was made of the same area in connection with the soil survey. In 1954, a reconnaisance ecological survey of the region was made by the senior author. Sixty-four sites were established in the map area on the major soils series and records taken of the soils, altitudes, exposure, slope, land use in the area, and probable history of each site.

TABLE 1.—AVERAGE MONTHLY AND ANNUAL PRECIPITATION IN INCHES AND MONTHLY MEAN TEMPERATURES IN DEGREES (F.) FOR REPRESENTATIVE STATIONS IN THE UPPER COLUMBIA VALLEY (4)

Station	Elevation, ft.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Precipitation (in.)														
Cranbrook	3,013	1.48	1.14	0.85	0.68	1.24	1.92	1.09	1.02	1.11	1.03	1.34	1.67	14.57
Canal Flats	2,653	1.51	1.25	1.03	.84	1.48	2.13	1.22	1.30	1.23	1.18	1.46	1.61	16.24
Invermere	2,840	.89	.58	.40	.53	1.14	1.63	1.03	1.37	1.10	.80	.68	1.11	11.26
Sinclair Pass	3,840	1.46	1.52	1.30	1.24	2.16	2.88	1.99	1.83	1.64	1.85	1.42	2.11	21.40
Brisco	3,000	1.44	.99	.83	.77	1.39	1.76	1.16	1.35	1.25	1.23	1.25	1.93	15.34
Golden	2,583	2.11	1.35	.93	.71	1.07	1.65	1.38	1.47	1.44	1.62	1.92	2.35	18.00
Monthly Mean Temperature (°F.)														
Cranbrook	3,013	16	21	32	43	51	58	63	62	52	42	29	20	41
Invermere	2,840	13	19	31	42	51	58	63	60	51	41	27	16	39
Sinclair Pass	3,840	11	17	27	38	46	51	57	55	48	39	23	16	36
Golden	2,583	12	18	31	42	51	58	63	60	52	41	28	17	39

TABLE 2.—AVERAGE LENGTH OF THE FROST-FREE PERIOD FOR REPRESENTATIVE STATIONS IN THE UPPER COLUMBIA VALLEY (3)

Station	Elevation ft.	Last Spring Frost			First Fall Frost			Av. frost-free period	Years
		Average	Earliest	Latest	Average	Earliest	Latest		
Invermere	2,840	May 28	May 11	June 23	Sept. 12	July 20	Oct. 7	108	33
Sinclair Pass	3,840	June 20	May 27	July 8	Aug. 18	July 20	Sept. 8	59	11
Golden	2,583	June 5	May 6	July 14	Sept. 9	July 17	Nov. 5	96	44
Donald	2,580	June 21	May 29	July 7	Aug. 25	July 28	Sept. 27	65	8

Where possible, at each location a representative site, roughly 200 ft. x 200 ft., was delimited and a species list made. Each species was given an abundance rating on a 1–5 scale. In addition, general notes were taken on the appearance of the site in relation to the trees, shrubs and herbs and, in some instances, the height, age, and diameter of the dominant trees were recorded as a guide to relative growth potential. In 1953 and 1956, tours were made through the map area and attempts made to correlate the soils and vegetation. All trips were made in company with the soils surveyors and a total of a month was spent in the map area. It was not possible to grid the map area uniformly with sites because of non-accessibility, but rather the location of the sites was based on the occurrence of the different soil series.

CLIMATE OF THE REGION

Since the climate of any region in a broad way determines the plant distribution and soil development therein, the climatic records of the Upper Columbia Valley section of the Rocky Mountain trench were studied in some detail as an aid to the study of the vegetation.

Temperature

There is surprisingly little variation in the mean annual temperatures in the Upper Columbia region (Table 1). There is a spread of only 3 degrees in the mean annual temperature between the valley and mountain weather stations and a similar spread between Golden and Cranbrook, which is about 70 miles south of Canal Flats. Cooler summers in the mountains largely account for the difference between these areas and the valleys, while warmer winters in the southern part of the Trench in the main account for the north-to-south spread.

The effect of altitude is seen on comparing the mountain station at Sinclair Pass with the nearby valley station at Invermere. The mean annual differences correspond roughly to the average decrease of 3.3°F. for every 1000-feet increase in altitude. There is considerably less difference in winter temperatures as compared with those of the summer between the two stations. The relatively high winter temperatures at these higher levels could possibly be the result of large-scale inversions of air which are known to occur in the Trench (2) and are brought about by air drainage.

The more extreme temperatures existing at Golden are reflected in the frost-free season (number of days with a minimum temperature above 32°F.) which is 96 days for Golden and 108 days for Invermere, frosts occurring both later in the spring and earlier in the fall at the former locality (Table 2).

Precipitation

The seasonal precipitation pattern throughout the Rocky Mountain Trench is not a simple one, even within the map area, and from the limited data available it is frequently difficult to determine where local effects exert their influence. In general, however, there is a shift from a winter maximum in the north at Golden to a summer maximum and June peak at Invermere and Sinclair Pass, then to an intermediate condition at Canal Flats. At this last location the winter precipitation increases again relative to that of the summer but June is retained as the peak month (Table 1).

At all stations, however, March and April are the driest months. A discussion of moisture regions in the southern part of the Rocky Mountain Trench is given by Kirk (12).

The highest annual precipitation occurs at the north end of the surveyed area (18.00 inches Golden) with a gradual decrease southward at Brisco (15.34 inches) and Invermere (11.26 inches). An increase takes place from here southward to Canal Flats (16.24 inches).

The effect of elevation can be seen by comparing Invermere (2840 feet) with Sinclair Pass (3840 feet), the annual precipitation being 11.26 inches and 21.40 inches respectively.

SOILS OF THE REGION

The chernozemic Dark Brown soils occur in scattered patches around Invermere and Lake Windermere and represent the northernmost extension of the grasslands in this region. They occur on gravelly parent materials in an area receiving an average of about 11 inches of precipitation per year. The profiles are characterized by a shallow dark brown A_1 horizon, and a strong lime concentration at from 8 to 11 inches below the surface. Reaction is from mildly alkaline at the surface to strongly alkaline (pH 8.4 to 9.0) below 11 inches.

Alternating with the Dark Brown soils, on areas where the solum becomes deeper, are Brown Wooded soils. They are characterized by a thin, grayish and slightly acid A_2 horizon, with a brownish B horizon (Figure 2). There is little or no clay accumulation and very little movement of sesquioxides in this soil group.

These soils seem to develop largely as a result of the influence of the coniferous trees. The organic matter is present as a thin forest litter (A_0 horizon) and does not accumulate in the mineral A_1 horizon. Under the semi-arid climate of this area there is only a slight downward movement of salts in the soil.

It is interesting to note the absence of Black soils in this region. Presumably wherever there is sufficient moisture for Black soils to develop, Douglas-fir invades the grasslands and Brown Wooded soils develop instead. These Brown Wooded soils occur roughly from Edgewater to Canal Flats.

The Gray Wooded soils begin to appear in the vicinity of Edgewater and become firmly established near Brisco. These soils are described by Moss and St. Arnaud (13) as being "characterized by thin A_0 horizons, thick, light grayish A_2 horizons, and brown to grayish brown, heavier textured B horizons. The C horizons, and sometimes the lower B horizons, are usually calcareous, although non-calcareous parent materials may also occur. Quite frequently a transitional A-B horizon is present. The A_1 horizon is very thin or absent". Both the soils and vegetation show increased development as a result of greater precipitation, compared with drier districts to the south.

The Brown Podzolic-Gray Wooded* and Podzol-Gray Wooded** soils begin between Spillimacheen and Parson and continue to the north end of the map area. The Brown Podzolic-Gray Wooded soils occur mostly on

*Leahey, A. *Personal communication.*
**Kelley, C. C., and W. D. Holland. Soil survey of the Upper Columbia River Valley, British Columbia. *Unpublished.*

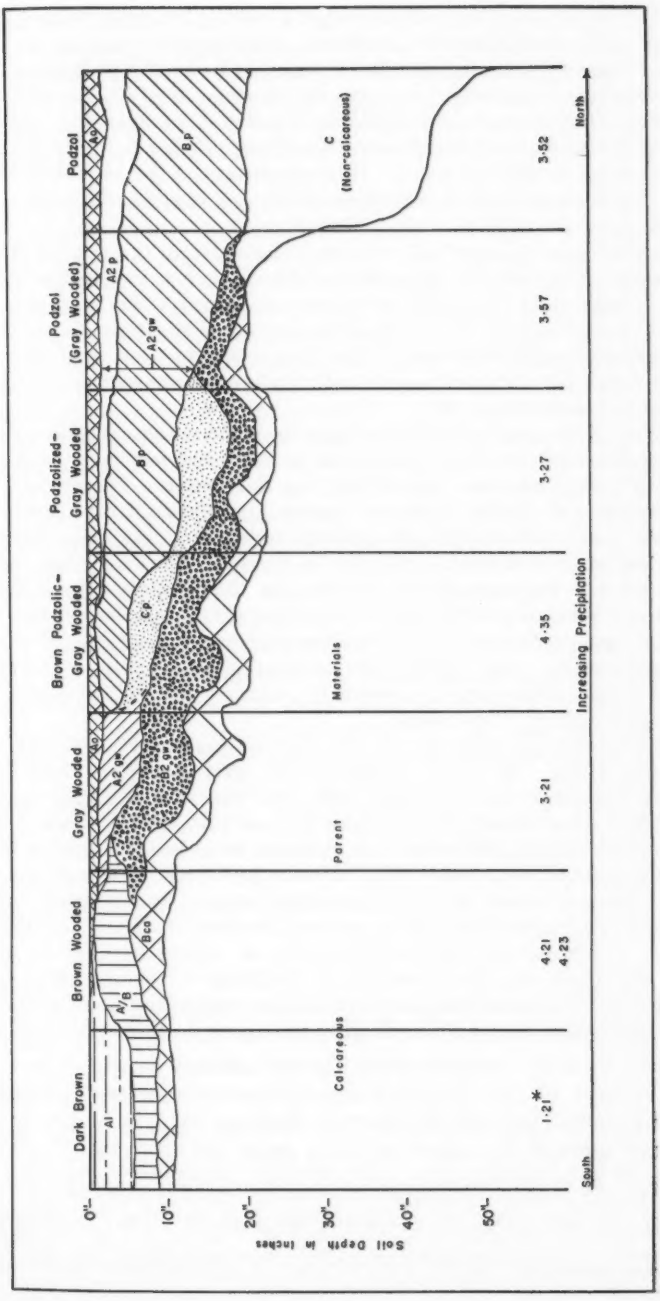

FIGURE 2. Sequences of soil profiles in the Upper Columbia Valley.

alluvial fans and are characterized by a brown to strong brown Bir(p) horizon under the forest litter, with only an occasional trace (up to $\frac{1}{4}$ inch) of an A_2 horizon between the forest litter and the Bir(p) horizon. The Bir(p) horizon is underlain by a grayish, leached, acid Cp horizon. This horizon is the remnant of the old Gray Wooded A_2 horizon that now forms the acid parent material for the secondary Brown Podzolic profile developing in the upper part of the solum. This secondary profile is underlain by a B_2gw that has a marked accumulation of clay and sesquioxides. The parent materials are generally strongly calcareous.

Podzol-Gray Wooded soils are fairly extensive in the north end of the map area. They show more profile development than the Brown Podzolic-Gray Wooded soils, the difference between the two profiles being a distinct, grayish white, acid A_2 horizon of 2 to 3 inches in thickness that occurs in the Podzol-Gray Wooded soil. It is interesting to note, also, that from Parson north the clay content of the soil increases, resulting in an increase in moisture-holding capacity.

Close to the north end of the map area, the process of eluviation has made sufficient progress for some soils to be considered as Gray Wooded-Podzol (1), or Podzol underlain by a clay B Horizon. The grayish white A_2 horizon and Bir(p) horizons become quite dominant. Some Gray Wooded characteristics remain and have to be recognized (e.g., lime close to the surface and remnants of a clay B_2 horizon), but these Gray Wooded characteristics have much less influence on the vegetation than those of the Podzol which has developed in the upper portion of the solum.

The spruce/fir zone lay outside the map area; consequently the soils were not studied. No attempt was made to correlate the soils and vegetation in detail, although in a number of instances the soils appeared to be podzolic (category V) in nature.

Azonal Alluvial soils are present on flood-plains on either side of the Columbia River. South of Golden, these soils support a semi-aquatic type of vegetation and are quite reduced. North of Golden, sand and gravel bars have developed and these support associations of white spruce and poplar. These soils show less evidence of reducing conditions, indicating better soil aeration. Alluvial fans are scattered along the valley edges. Some of these fans have immature profiles and generally support stands of black poplar and white spruce with some Douglas-fir on the drier slopes. A number of fans are calcareous in nature because of seepage water and these are dominated by a deciduous forest and shrub cover, largely aspen. These alluvial soils embrace a wide variation in soil texture, with a fluctuating high water-table generally being the dominating influence.

VEGETATION OF THE REGION

The flora of the Rocky Mountain Trench from the International Border to Brisco has been discussed by Eastham (9). Brief discussions of the forest types of the Upper Columbia region are given by Whitford and Craig (17) and Halliday (11). No ecological studies have been published to date for this region. Krajina* has made an intensive study of the hemlock forests of the western section of the Big Bend region of the Columbia River.

*Krajina, V. Ecological classification of hemlock forests, Columbia River basin. Univ. Brit. Columbia, Dept. Botany, mimeo. report. 1953.

The distribution of the native vegetation in the Upper Columbia Valley between Bluewater Creek and Canal Flats is influenced largely by decreasing precipitation and increasing evaporation from north to south and by differences in elevation on the east-west valley slopes. Modifications, however, result from variations in topography and soils. The driest vegetation zone centres around Invermere and Edgewater. Somewhat more moist conditions occur southwards from there, but the greatest changes occur northward and with increasing elevations up the valley slopes.

From Brisco south, the valley widens out considerably and the climate becomes drier than that of the northern half of the map area. Another climatic break seems to occur in the vicinity of Golden, the precipitation increasing rapidly from here northward. This change is accentuated, probably by the decreasing influence of the Dogtooth Range and the modifying influence of the mountain gaps. In a broad way, then, the map area can be divided into three sections based on the vegetational zones which occupy the areas adjacent to the valley floor. The sections are: Bluewater Creek to Golden, which is transitional between the Douglas-fir/pinegrass and cedar/hemlock zones; Golden to Brisco, which is mostly Douglas-fir/pinegrass sub-zone; and Brisco to Canal Flats, which is predominantly a dry Douglas-fir/wheatgrass sub-zone. In addition to the above three, the cedar/hemlock zone enters the north end of the map area at lower elevations but is soon confined to the upper benches southward towards Golden. Practically all the spruce/fir zone lies at elevations above the map area. Within each zone minor differences in soils, local climate, and topography result in variations in the plant associations that occur.

The vegetation over most of the region has been disturbed greatly by both fires and logging, and in the southern sector by grazing as well. As a result, practically all stages of secondary plant succession are to be found and relict areas are rare, especially in the forest zones.

Because of the complexity of the vegetation patterns and the limitations imposed by the survey, little effort has been made to classify the vegetation beyond the zonal grouping. A number of different plant communities were observed to exist within each zone, but little could be done beyond pointing out the presence of some of the more obvious and important ones.

Douglas-fir Zone

For the purposes of this survey the Douglas-fir zone has been broken down into two sub-zones which have been designated as Douglas-fir groveland and Douglas-fir forest. Zonal classification for each of the above hardly seemed warranted without further study.

(a) *The Douglas-fir Groveland Sub-zone*—This sub-zone occupies the most arid portions of the Upper Columbia Valley. It is best developed in the dry benches and lower slopes below 2800-foot elevation from somewhat north of Edgewater to Invermere, although isolated spots occur south to Dutch Creek (Figure 3). It occurs on areas which have from 10 to 15 inches annual precipitation.

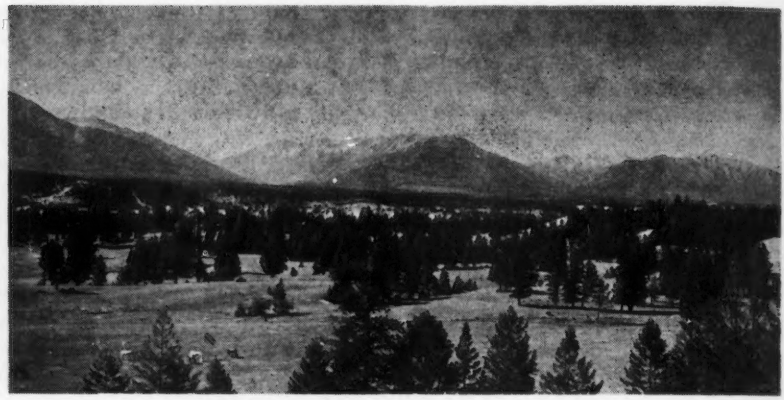

FIGURE 3. The Douglas-fir groveland sub-zone south of Invermere.

This sub-zone lies adjacent to the yellow pine/Douglas-fir ecotone which occurs to the south, the principal difference being the absence of yellow pine (*Pinus ponderosa*). The yellow pine zone occurs to the south of the map area where it consists of two principal associations, yellow pine/bitter brush, and yellow pine/wheatgrass. These associations are essentially the same as described by Daubenmire (8) for northern Idaho. Similar associations are also reported by Brayshaw* for the southwestern interior of British Columbia. With increased precipitation or soil moisture-holding capacity the groveland sub-zone develops into the Douglas-fir forest sub-zone.

The groveland sub-zone has an open park-like or savannah appearance with islands of grassland, which may contain widely scattered scrubby trees of Douglas-fir (*Pseudotsuga menziesii*), surrounded by open stands of rather stunted trees of the same species which occur on slightly moister locations. Douglas-fir is the sole tree found in this zone except for the tree-like Rocky Mountain Juniper (*Juniperus scopulorum*). There appears to be no marked invasion of the grassland by Douglas-fir reproduction. The more mesic Douglas-fir/pinegrass association extends into the sub-zone as an edaphic climax in moist draws enabling lodgepole pine (*Pinus contorta*) and aspen (*Populus tremuloides*) to become established locally.

This sub-zone appears to be, in reality, an alternation of two principal associations, namely, fescue/snowberry and Douglas-fir/ wheatgrass. The fescue/snowberry association, which may contain scattered, stunted trees of Douglas-fir, seems to be the climatic climax. This association occurs on Dark Brown soils which represent the only truly grassland soils found in the map area. This association is characterized by the occurrence in nearly equal abundance of bluebunch wheatgrass (*Agropyron spicatum* including var. *inerme*) and fescue (both *Festuca idahoensis* and *F. scabrella*). These grasses are accompanied by a great variety of forbs and shrubs, such as snowberry (*Symphoricarpos occidentalis*), pussytoes (*Antennaria parvifolia*),

*Brayshaw, T. C. Classification of ponderosa pine stands in southwestern interior of British Columbia. Univ. Brit. Columbia, Dept. Botany, special report. 1954.

FIGURE 4. The Douglas-fir forest sub-zone (Douglas-fir/pinegrass association) north of Edgewater.

timber milk-vetch (*Astragalus decumbens* var. *serotinus*), yellow aster (*Chrysopsos villosa*), brown-eyed Susan (*Gaillardia aristata*), gromwell (*Lithospermum ruderale*), erigeron (*Erigeron filifolius and E. corymbosus*), Saskatoon berry (*Amelanchier alnifolia*), Kinnikinnick (*Arctostaphylos uva-ursi*), rose (*Rosa sp.*), and soopolallie (*Shepherdia canadensis*).

The alternating association (Douglas-fir/wheatgrass) occurs as an edaphic climax on Brown Wooded soils in swales and draws around Invermere and as climatic climax on the benches above Edgewater. This association is also reported by Brayshaw (*see footnote p. 336*) for the southwestern interior of British Columbia. There is an increase in snowberry and rose in this association; otherwise the ground cover is similar to that occurring in the fescue/snowberry association. Pinegrass (*Calamagrostis rubescens*) may occur locally, and Wheeler bluegrass (*Poa nevadensis*) is common.

Restricted in occurrence to the driest sites and shallow soils is an edaphic climax of the bluebunch wheatgrass/fescue association. The herbaceous cover is dominated by bluebunch wheatgrass notably the rhizomatic form.* Associates are Idaho fescue, rough fescue and Junegrass (*Koeleria cristata*).

The above association occurs farther south in the Trench as a climatic climax on Dark Brown soils. The grasslands in this area resemble those described by Daubenmire (6) for Washington, although the proportion of forbs is much less. They are closely similar to those described by Tisdale (15) for southern interior British Columbia. Both the fescue/snowberry

*Daubenmire R. (5), observed and described the occurrence of this form in the northwestern United States.

and the wheatgrass/fescue associations of this section of the Columbia have the general appearance of being more xeric and producing less vegetative growth than similar associations observed in other regions.

Sandgrass (*Calamovilfa longifolia*) occurs locally on sand dunes south of Invermere while rabbit brush (*Chrysothamus nauseosus*), silverberry (*Elaeagnus commutata*), and crawling juniper (*Juniperus horizontalis*) are common on sandy soils. A few species, widespread on the Great Plains but rare in British Columbia, are also common, such as plains reedgrass (*Calamagrostis montanensis*) and scarlet mallow (*Sphaeralcea coccinea*). It was observed that bitter brush (*Purshia tridentata*) which is abundant south of Canal Flats does not extend into the map area.

Most of this zone has been heavily grazed and the desirable bunchgrasses have largely been replaced by inferior grasses and weeds, notably Sandberg's bluegrass (*Poa secunda*), pussytoes, dandelion (*Taraxacum* spp.) Cheatgrass (*Bromus tectorum*), Junegrass, plains reedgrass, and pasture wormwood (*Artemisia frigida*). In the moist swales, Kentucky bluegrass (*Poa pratensis*) dominates.

Grazing constitutes the principal land use of this zone because the slow growth and heavy branching of the Douglas-fir make it useless for commercial timber. Harvesting of Douglas-fir for Christmas trees, however, is an industry of some importance.

(b) *Douglas-fir Forest Sub-zone.* The Douglas-fir forest sub-zone occurs generally in areas with 15 to 18 inches precipitation at elevations immediately above the preceding one (up to about 3500 feet in the southern section of the map area) and replaces it southward to Canal Flats and northwards to Brisco as the precipitation increases (Figure 4). It also extends northward to around Donald on dry slopes. It is the most extensive plant community in the map area and consists of a number of different plant associations. It appears to be similar to that which occurs in the Okanagan and Thompson valleys and Cariboo region at similar elevations (14), (16). It differs from the Douglas-fir zone occurring in northern Idaho and Washington in not having a Pseudotsuga/Physocarpos association and in having a better developed Pseudotsuga/Calamagrostis association (8).

Douglas-fir is the climax tree, generally forming somewhat open stands. Lodgepole pine and aspen are seral species and frequently dominate areas after logging or fire. Lodgepole pine is generally dominant on the drier, shallow soils, and aspen on the deeper, moist soils. South of Invermere at higher elevations (generally above 3400 feet), western larch (*Larix occidentalis*) may be present as a seral species and along with lodgepole pine often plays an important role in fire successions. Yellow pine, frequently another seral species of the zone in other districts, was virtually absent throughout the study area, being found only occasionally from Canal Flats to a few miles north of Dutch Creek on the west side of Columbia Lake.

White spruce (*Picea glauca*), and to a lesser extent Engelmann spruce [*Picea engelmanii* (10)], is a conspicuous member of this sub-zone in the section of the map area north of Brisco. On many locations, Douglas-fir shares climax status with the white spruce which adapts itself well to Douglas-fir habitats. This adaptation has also been observed by Daubenmire (7). White spruce also dominates many low fans and river terraces.

The Douglas-fir/pinegrass association constitutes the climatic climax on Gray Wooded soils of this sub-zone. The principal shrubs to be found are soopolalie, rose, and a group of low evergreens such as twin flower (*Linnaea borealis*), wintergreen (*Pyrola secunda*) and kinnikinnick. The latter species shares dominance with pine-grass, depending in part at least on the fire history of the site since it is very susceptible to killing by fire. Willows (*Salix* spp.) and dwarf blueberry (*Vaccinium caespitosum*) are common in the sub-zone during early seral stages, especially after fires. The dominant herb throughout the subzone is pinegrass while other important herbs include showy aster (*Aster conspicuus*), timber milk-vetch, yellow peavine (*Lathyrus ochroleucus*), wild strawberry (*Fragaria* spp.) and heart-leaved arnica (*Arnica cordifolia*). Yellow peavine and American vetch (*Vicia americana*) are most common under aspen on the moist sites. Blue-bunch wheatgrass and thickspike wheatgrass (*Agropyron dasystachium*) occur frequently on dry, open knolls in the lower part of the zone. Mosses and liverworts are not abundant in the sub-zone.

On deeper soils and swales in the lower part of the zone snowberry increases in importance, forming a Douglas-fir/snowberry association. A general increase in the abundance of shrubs can be expected in this latter community such as snowberry (*Symphoricarpos albus*), rose, flat-topped spiraea (*Spiraea lucida*), Oregon grape (*Berberis repens*), silverberry, soopolallie, and Saskatoon berry.

A Douglas-fir/white spruce community is widespread along the upper and northern parts of the Douglas-fir forest sub-zone on Podzol Gray Wooded soils. This community closely resembles that of the Douglas-fir/pinegrass association with the notable addition of white spruce and some of the undercover species common in the cedar/hemlock zone, Douglas-fir white spruce, lodgepole pine, and aspen are the principal trees. Some white birch (*Betula papyrifera*) is generally present but other trees of the cedar/hemlock zone are absent. Soopolallie becomes the most prevalent shrub in the understory and frequently shares dominance with the pine grass. Twin-flower, kinnikinnick, rose, thimbleberry, false box, willow, and Saskatoon-berry are the most common shrubs of this association. The herb cover contains such species as pinegrass, heart-leaved arnica, showy aster, wild strawberry, prince's pine (*Chimaphila umbellata*), ricegrass (*Oryzopsis asperifolia*), and sarsaparilla (*Aralia nudicaulis*).

This community has been observed by the senior author in the Kettle Valley region and to some extent in the Thompson River region. It will require further study before its true position and significance can be ascertained as it has not yet been observed in a climax or near-climax state.

In many ways this community seems to be transitional between the Douglas-fir forest sub-zone and cedar/hemlock zone although closer to the former. This condition parallels that of the soils with the Podzol-Gray Wooded and Brown Podzolic-Gray Wooded being transitional between the Gray Wooded and Podzol great soil groups. It might be postulated that there is sufficient podzol development to start many of the herbaceous components of the cedar/hemlock zone but still not sufficient to permit the establishment of characteristic trees of this zone.

A white spruce association forms an edaphic climax on lower river benches and many outwash slopes and fans bordering the Columbia River from around Brisco northward at elevations of about 2600 feet. White spruce is dominant under climax conditions although cottonwood (*Populus trichocarpa*), aspen and white birch are common. After clearing or burning, aspen and birch dominate and are accompanied by a wide variety of herbaceous species including many grasses. Douglas-fir is also common on many of the better drained sites especially in early succession stages. Occasionally some alpine fir (*Abies lasiocarpa*) reproduction is present. Sub-irrigation would seem to be an important characteristic of this association.

The undercover, especially in seral stages, is dominated by a wide variety of shrubs, and dominance appears to depend somewhat on depth to water table or the moisture-holding capacity of the soil. The principal species are soopolallie, snowberry, rose, Saskatoon berry, Oregon grape, smooth maple (*Acer glabrum*) and willow. Also common are flat-topped spiraea, bunchberry (*Cornus canadensis*), red-osier dogwood (*Cornus stolonifera*), and twinberry. Herbs constitute a minor part of the flora depending on the density of the canopy, the most common being ricegrass, yellow peavine, American vetch, and sarsaparilla. If the canopy remains open and dominated by aspen, these areas provide excellent grazing and may have an undercover dominated by Kentucky bluegrass and white clover (*Trifolium repens*) along with snowberry.

Close to the north end of the map area the Douglas-fir zone gives over to the cedar/hemlock zone above about 3100 feet. South of here the latter zone becomes intermittent above 3400 feet except for favoured locations, such as stream terraces and east-facing slopes, and is frequently replaced by the Englemann spruce/alpine fir zone. In general, the cedar/hemlock zone lies between the Douglas-fir and spruce/fir zones where soil moisture is adequate, precipitation is sufficiently high and the winter temperatures not too low.

Both logging and grazing are extensively carried on in the Douglas-fir zone. Douglas-fir is the principal commercial tree and produces high quality lumber, although the growth increment is not so great as that characteristic of this species in the more moist zones. This zone generally provides good summer range for cattle because of the open nature of the tree cover. The best grazing in this zone is to be found in the region south of Brisco, where ranchers can also utilize the Douglas-fir/wheatgrass zone for grazing. Christmas-tree cutting is carried on extensively in the lower part of this zone south of Brisco where the stands are open and growth relatively slow so that the young trees tend to bush out well.

Cedar/Hemlock Zone

Although the cedar/hemlock zone occurs north of Golden at elevations above 3100 feet on Podzol soils it is more typically represented north of the map area in the Big Bend section of the Trans-Canada Highway (Figure 5). It is felt that possibly the presence of lime close to the surface prevents a greater expression of the zone in this sector. Farther north and west, however, on parent materials lower in lime, greater podzol development occurs and the expression of the cedar/hemlock zone becomes more typical. The

FIGURE 5. The cedar/hemlock zone near Bluewater Creek. Mature trees are spruce, Douglas-fir; reproduction consists of Douglas-fir, spruce, alpine fir, cedar and hemlock.

zone is found intermittently south of Golden, inserted between the Douglas-fir and spruce/fir zones, although principally at elevations above the map area. It is best represented in localities with an annual precipitation in excess of about 25 inches.

A number of associations occur in this zone due to variations in soils, topography and precipitation. In the climatic climax western red cedar (*Thuja plicata*) and/or western hemlock (*Tsuga heterophylla*) dominate, the cedar generally appearing first as the elevation increases. A wide variety of seral trees occur, including white pine (*Pinus monticola*), lodgepole pine, alpine fir, Englemann spruce, Douglas-fir, aspen, white birch and cottonwood. Because of the extensive disturbance by fire and logging most of the area is now in a mixture of Douglas-fir and spruce. There is, however, considerable cedar and hemlock reproduction. Large stands of lodgepole pine occur on shallow or coarse-textured soils and are principally a result of severe burns.

Shrubs which dominate the understory become relatively sparse as the tree cover closes in. Common shrubs are red-osier dogwood, copper bush (*Cladothamnus pyrolaeflorus*), white rhododendron (*Rhododendron albiflorum*), false azalea (*Menziesia ferruginea*), false box (*Pachystima myrsinites*), rose (*Rosa sp.*), mountain ash (*Sorbus sitchensis*), white-topped spiraea, thimbleberry (*Rubus parviflorum*), honeysuckle (*Lonicera involucrata* and *L. utahensis*), high-bush cranberry (*Virburnum trilobum* and *V. edule*), and currants (notably *Ribes viscosissimum*) along with the common herbs, prince's pine, queen's cup (*Clintonia uniflora*), twinberry, foam flower (*Tiarella unifoliata*), meadow rue (*Thalictrum occidentale*), and sarsaparilla. A heavy moss cover is also characteristic of this zone.

Bracken fern (*Pteridium aquilinum*), common in this zone farther north, was not observed in the map area.

Within this zone and in moist locations in those adjacent, an edaphic climax sometimes occurs in which cedar makes up about 80 per cent of the stand. This association occurs on low stream terraces and seepage areas in which the ground-water level is near the surface and the soil constantly moist but fairly well drained. It is not generally found over large areas but occurs locally over a wide range. White and Englemann spruce and cottonwood occur as the principal associates of the cedar although other trees of the zone may also be found. The undercover is generally sparse and mostly shrubby with devil's club (*Oplopanax horridus*), thimbleberry, fern (*Athyrium filix-femina*), horsetail (*Esquisetum spp.*) and sarsaparilla being the principal species, along with a dense cover of moss where the ground is not too much disturbed. The two associations described above correspond closely to the Thuja-Tsuga/Pachystima and Thuja-Tsuga/Oplopanax associations described by Daubenmire (8) for northern Idaho and Washington.

Logging constitutes the principal land use of this zone. Douglas-fir reaches its maximum growth rate for the Interior in this zone and is eagerly sought after. However, white pine, cedar, spruce, fir, and hemlock are also harvested extensively. The cedar/hemlock zone is the most productive of lumber of all the zones in the Upper Columbia, especially with respect to Douglas-fir, white pine and spruce. Because of the high annual precipitation occurring in this zone and in those which lie above it, watershed values are also important.

Spruce/Fir Zone

The Englemann spruce/alpine fir or sub-alpine zone is found in the Trench, generally above 3600 feet. Where there is a cedar/hemlock zone, the sub-alpine zone is found at elevations above it. Where the cedar/hemlock is excluded or intermittent, the spruce/fir zone may adjoin the Douglas-fir zone directly. This sub-alpine zone extends to the timberline and meets the alpine tundra in this region.

The zone is characterized by the dominance of Englemann spruce and alpine fir, the former generally being more common. Associated seral trees include Douglas-fir, white pine, aspen, and lodgepole pine. The latter species frequently forms dense stands after disturbance by fire. After logging, however, spruce may come in directly. Shrubs dominate the understory along with a dense moss cover. The principal shrubs are Labrador tea (*Ledum groenlandicum*), false azalea, mountain ash, huckleberry (*Vaccinium scoparium*), and white rhododendron, along with soopolallie, rose, bunchberry, false box, mountain cranberry (*Vaccinium vitis—idaea* var. *minus*), and creeping wintergreen (*Chiogenes hispidula*).

Characteristic herbs are ricegrass, queen's cup, meadow rue, twinflower, wintergreen (*Pyrola chlorantha*, P. *asarifolia*), mitrewort (*Mitella stauropetala*), prince's pine, and one-flowered pyrola (*Moneses uniflora*). Huckleberries and blueberries increase greatly after fires.

A number of different associations occurring within this zone on different habitat types were not considered as they are beyond the scope of the present study.

Fires have been destructive in both the cedar/hemlock and spruce/fir zones. Although they are not so common as in the drier zones, they are more devastating because of the heavy vegetative growth.

Logging is the principal land use of this zone because of the rapid growth rate of the trees, heavy shrub cover and lack of good forage.

Hydroseres

Another broad vegetation belt occupying considerable area is that of the Columbia River Flats which extend from Athalmer to Golden. The soils on these flats are highly gleyed, alluvial soils. The Columbia River winds through the valley floor and subjects it to prolonged annual flooding. Extensive swampland and flood meadows occur resulting in a mosaic of plant communities with wetland, semi-aquatic, and aquatic vegetation. Ponds of water-lily (*Nuphar polysepalum*), cattail (*Typha latifolia*) and other aquatic species are surrounded by meadows which are composed principally of sedges (*Carex* spp.), flood-tolerant grasses (notably *Agrostis stolonifera*) and weeds. Ribbons and islands of shrubs such as willow, water birch (*Betula occidentalis*), and cottonwood form on the lower levees. On higher ground, which is subject to less prolonged flooding, additional species such as aspen, spruce, hawthorn (*Crataegus columbiana*), snowberry, and wild rose appear. Along the edges of the valley floor and on higher ground these communities give over to the white spruce community discussed earlier. The principal land use of these floodlands at present is as wildlife refuges. The possibility for drainage and reclamation is poor.

North of Golden, below the confluence of the Kicking Horse and Blaeberry Rivers, the Columbia increases its rate of flow and gravel bars appear to replace the swampland. The azonal soils in this sector are less gleyed than those south of Golden, indicating better soil aeration. Yellow dryas (*Dryas drummondii*) dominates the most recently established bars although cottonwood and white spruce soon invade and form dense stands on the large bars. On higher bars lodgepole pine, willow, and aspen are soon added to the community over a sparse ground cover consisting mainly of soopolallie, black birch, juniper, shrubby cinquefoil, ricegrass, yellow dryas, peavine, vetch and aster.

DISCUSSION

Neither the soils nor vegetation survey was on a sufficiently detailed scale to uncover more than the broad relationships or general trends existing between soils and vegetation within the Upper Columbia valley. Such a project would be a major undertaking in view of the complexity of both the soils and vegetation patterns and far beyond the scope of the present survey, which was designed primarily to determine the agricultural potential and water requirements of the valley. For these reasons the soils and vegetation relations have been drawn for the most part at the great soil group and vegetation zone levels respectively.

Over the region as a whole, precipitation seems to be the principal factor governing both vegetative growth and soil formation. Within the

main Trench there is a parallel relationship between the kind of soils and the native vegetation.

A number of factors operate, however, to permit intermingling of the vegetation zones and soil groups. Rough topography and sharp differences in slope and exposure influence the vegetation distribution greatly.

Type of soil, stage of development, thickness of one or more horizons, distance to and type of parent material, degree of podzolization, and the presence of clay or gravel strata may all affect the type of vegetation growing on an area. For example, shallow and coarse-textured soils and the presence of gravel layers may reduce the moisture-holding capacity of the soil to the point where the vegetation is much more xerophytic than in the surrounding soils with higher water-holding capacities.

The relationship that exists between the soils and vegetation in the main Trench does not appear to hold in the tributary valleys to the west where the soil is different.

Most of the soils in the main body of the Trench have been derived from highly calcareous parent materials. Soils that are derived from the Purcell Mountains, however, are considerably lower in lime. For example, in a side valley west of the Steamboat Mountain, the Douglas-fir/pinegrass association is found over what appears to be Brown Wooded soil. This soil, however, has a brighter colour than that found in the main Trench. Comparable soil in the main Trench supports only the Douglas-fir/wheatgrass association while the Douglas-fir/pinegrass association is found over Gray Wooded soils. On Gray Wooded soils at higher elevations in the side valley the Douglas-fir/white spruce association appears.

ACKNOWLEDGEMENTS

Plant collections were made of most of the common species in each zone and specimens deposited in the herbarium at the Range Experimental Farm, Kamloops, B.C., and Botany Division, Science Service, Ottawa, Ont. The authors are deeply indebted to J. A. Calder, Botanist, Botany Division, Ottawa, for identification of the material submitted.

The writers are greatly indebted to R. Daubenmire, Professor of Plant Ecology, Washington State College; L. Farstad, Soil Surveyor, Experimental Farms Service, Canada Department of Agriculture; E. W. Tisdale, Head, Department of Range Management, University of Idaho, and A. Leahey, Head, Soils Surveys, Canada Department of Agriculture, for detailed reviews of this paper and many valuable criticisms.

REFERENCES

1. Bowser, W. E. Report on Podzol-Gray Wooded intergrades. Rept. 1957 meetings, West Section, Natl. Soils Survey Comm., pp. 13-16. 1957.
2. Chapman, J. D. The climate of British Columbia. Trans. 5th Brit. Columbia Natural Resources Conf., pp. 8-54. 1952.
3. Connor, A. H. The frost-free season in British Columbia. Can. Dept. Transport, Meteor. Div., Toronto. 1949.
4. Department of Agriculture. Climate of British Columbia. Rept. for 1953. Queen's Printer, Ottawa. 1954.
5. Daubenmire, R. The taxonomy and ecology of *Agropyron spicatum* and A. *inerme*. Bull. Torrey Botan. Club 66:327–329. 1939.

6. Daubenmire, R. An ecological study of the vegetation of south-eastern Washington and adjacent Idaho. Ecol. Monographs 12:53-79. 1942.
7. Daubenmire, R. Vegetation zonation in the Rocky Mountains. Botan. Rev. 9:325-393. 1943.
8. Daubenmire, R. Forest vegetation of northern Idaho and adjacent Washington, and its bearing on concepts of vegetation classification. Ecol. Monographs 22:301-330. 1952.
9. Eastham, J. W. Observations on the flora of the southern Rocky Mountain Trench in British Columbia. Trans. Roy. Soc. Can., Sect. V, 43, pp. 1-19. 1949.
10. Gorman, E. H. The occurrence of spruce in the interior of British Columbia. British Columbia Forest Serv. Tech. Pub. T. 49. 1957.
11. Halliday, W. E. D. A forest classification for Canada. Dominion Forestry Service Bull. 89. 1937.
12. Kirk, D. W. Moisture regions in the east Kootenay lowlands of British Columbia. Sci. Agr. 31:15-24. 1951.
13. Moss, H. C., and R. J. St. Arnaud. Gray Wooded (podzolic) soils of Saskatchewan, Canada. J. Soil Sci. 6:293-311. 1955.
14. Spilsbury, R. H., and E. W. Tisdale. Soil-plant relationships and vertical zonation in the southern interior of British Columbia. Sci. Agr. 24:395-436. 1944.
15. Tisdale, E. W. The grasslands of the southern interior of British Columbia. Ecology 28:346-382. 1947.
16. Tisdale, E. W. Grazing of forest lands in interior British Columbia. J. Forestry 48:856-860. 1950.
17. Whitford, H. N., and R. D. Craig. Forests of British Columbia. Can. Comm. Conservation, Comm. on Forests. 1918.

INVESTIGATIONS ON THE SPORTING PROCESS IN GREENHOUSE CHRYSANTHEMUMS[1]

D. R. SAMPSON, G. W. R. WALKER[2], A. W. S. HUNTER AND MARIE BRAGDØ[3]

Received for publication November 29, 1957]

ABSTRACT

The chromosome numbers of 56 varieties of greenhouse chrysanthemums were determined. Fifty-one varieties belonged to 10 'families' of sports and the chromosome numbers of the sports were compared with those of their vegetative parents. Sporting, mostly flower colour mutation, was accompanied by the gain or loss of a few chromosomes in about 30 per cent of the cases. Two plants with different chromosome numbers but with the true varietal flower colour were found.

The most frequent chromosome number in the authors' material was 2n = 57. The range was 2n = 45-64. Mitotic irregularities and chromosome number variation within individuals were observed. Attempts to induce sporting by hot water treatment failed.

Varieties with large inflorescences had higher chromosome numbers (2n = 58-64) than varieties with medium or small inflorescences (2n = 54-58), but in most of the material varieties with small inflorescences differed little in chromosome number from those with medium-sized inflorescences. Five additional varieties with very small inflorescences had lower chromosome numbers (2n = 45-55).

INTRODUCTION

Chrysanthemum varieties frequently sport to new varieties. The sports, in turn, may give rise to additional sports so that 'families' of sports containing ten or more commercial varieties are not uncommon. The importance of this process is indicated by the survey of Wasscher (8) who found that at least 29.5 per cent of the 633 varieties he investigated originated as sports.

Modern garden and greenhouse chrysanthemums are probably derived from hexaploid (2n = 54) wild species, but Shimotomai (5), Dowrick (3) and Debuisson (2) report that many, if not most, cultivated varieties are aneuploids. Dowrick (3) observed that sports which were vegetatively related frequently had different chromosome numbers, and also that cells of one plant sometimes differed in chromosome number. He therefore concluded that the gain or loss of a few chromosomes caused by mitotic irregularities was a major factor in the sporting process.

This study was undertaken to test Dowrick's hypothesis that sporting in chrysanthemums is caused by somatic chromosome variation. The chromosome numbers of 51 varieties of 10 families of sports were determined. Most of the sports in each family differed in flower colour. Eight families are of American origin and provide comparisons with the work of Shimotomai on Japanese varieties, and of Dowrick on English varieties.

---

[1] Contribution No. 920 from the Horticulture Division, Experimental Farms Service, Canada Department of Agriculture, Ottawa, Ont.

[2] Now Associate Cytogeneticist, Dept. of Plant Science, University of Alberta, Edmonton, Alta.

[3] National Research Council of Canada Post-doctoral Fellow, 1956-57; on leave of absence from the Institute of Genetics and Plant Breeding, Agricultural College of Norway, Vollebekk, Norway.

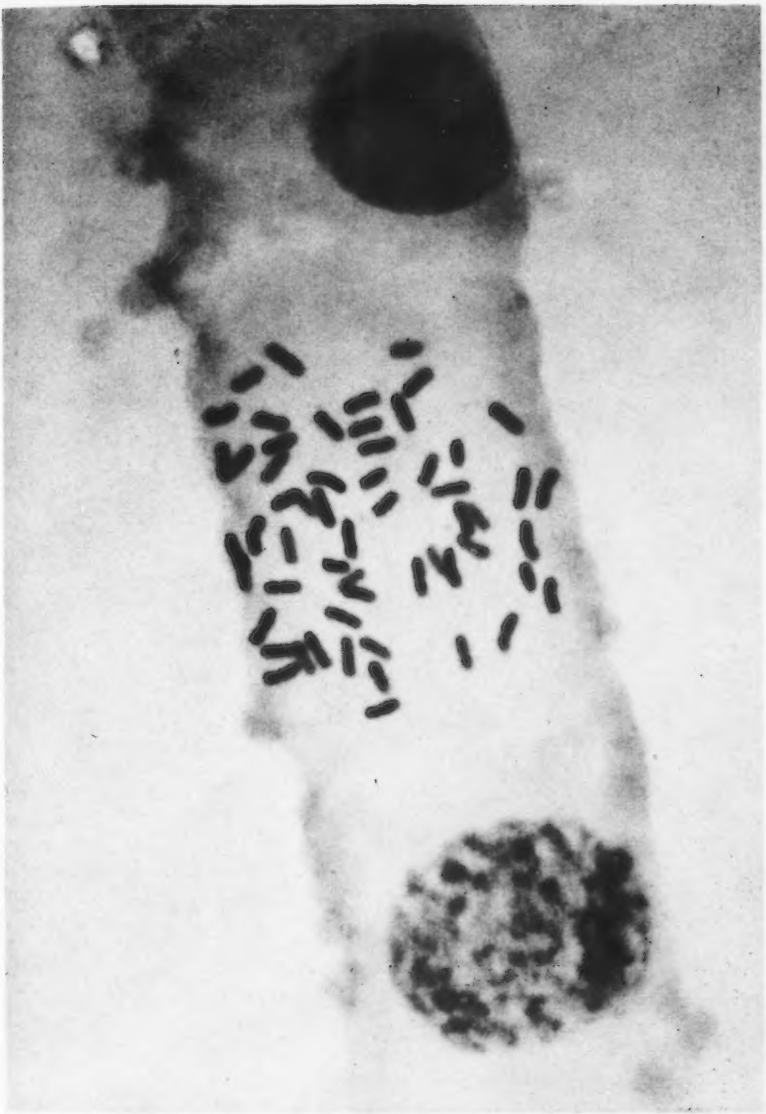

FIGURE 1. Root tip chromosomes of Bronze Orchid Queen after treatment with colchicine and staining with acetic orcein.

FIGURE 2. Root tip mitosis in Yellow Lace showing a chromosome bridge at late anaphase. This material was not colchicine treated.

METHODS AND MATERIAL

Chromosome counts were made on root tip material which was pretreated in a 0.2 per cent aqueous solution of colchicine for 3 hours and then fixed in a mixture of three parts absolute alcohol to one part carmine-saturated glacial acetic acid. A few drops of ferric acetate were added to the fixative. At first acetic-lacmoid stain was used (7) but most of the material was stained for 5 minutes in 1 per cent acetic-orcein following hydrolysis for 15 minutes in a mixture of ten parts of 1 per cent acetic-orcein to one part normal hydrochloric acid. After staining, the material was transferred to a drop of orcein on a slide, teased apart, the cover slip added and pressure applied. Excellent preparations, which permitted exact chromosome counts, were obtained (Figure 1). Unfortunately morphological differences were not great enough to characterize individual chromosomes.

All plants studied were raised from cuttings in the greenhouse. Usually three plants of each variety were examined. These were then flowered and checked for trueness to type.

RESULTS AND DISCUSSION

Chromosome Numbers of the Varieties

Table 1 gives the chromosome numbers found in 51 chrysanthemum varieties. The families of sports are listed in the order of increasing inflorescence diameter.

The two pompon varieties, Bronze Bulkeley and Dark Pink Bulkeley, have $2n = 54$ and 55 respectively. Both are derived from the light lavender-pink Mrs. Morgan G. Bulkeley, of unknown chromosome number. Therefore, at least one sport differs in number from the original variety.

Figure 3 shows the derivation of four colour sports from the original Masterpiece. No change in chromosome number was found (Table 1).

The white variety Shasta ($2n = 56$) sported to Yellow Shasta ($2n = 56$) which in turn sported to Cream Shasta ($2n = 55$).

The origin of eight colour sports in the Valencia family is shown in Figure 3. All except Yellow Valencia ($2n = 56$) have the same chromosome number as the original Valencia ($2n = 57$). Yellow Valencia is the most vigorous of the Valencia family. Valencia was bred by De Petris of Detroit, Michigan, from the cross between the English variety Lily Neville and Cumming's Korean daisy.

Queen's Lace, which was bred by W. E. Duffett from material imported from Japan, gave rise to two colour sports and one morphological variant (Figure 3). There was one change in chromosome number. One of the chromosomes in all four members of the Lace family was so much shorter than the others that it often appeared as a dot.

The two members of the News family, bronze Detriot News and its yellow sport Good News, are interesting because they sport to each other. Possibly the yellow sports to bronze more frequently. Both varieties have $2n = 56$ chromosomes.

TABLE 1.—CHROMOSOME NUMBER OF CHRYSANTHEMUM VARIETIES

Variety	Number of plants	Number of root tip cells			
		Chromosome number			
		54	*55*	*56*	*57*
Bulkeley Family					
Bronze Bulkeley	2	14			
Dark Pink Bulkeley	3		7		
Masterpiece Family					
Masterpiece	3				7
Rose Masterpiece	3				8
Salmon Masterpiece	3				6
Bronze Masterpiece	2				7
Dark Bronze Masterpiece	3				8
Shasta Family					
Shasta	2			6	
Yellow Shasta	3			7	
Cream Shasta	3		7		
Valencia Family					
Valencia	3				7
White Valencia	3				6
Dark Valencia	3				7
Salmon Valencia	3				7
Orchid Valencia	3				6
Apricot Valencia	2				6
Dubonnet Valencia	3				8
Crimson Valencia	3				8
Yellow Valencia	3			6	
Lace Family					
Queen's Lace	3		6		
Yellow Lace	3		11	1	
Hooked Yellow Lace	3		8		
Gold Lace	3	10			
News Family					
Good News	3			8	
Detroit News	2			10	
Indianapolis Family					
Indianapolis Pink	2				7
Indianapolis White	2				11
Improved Indianapolis White	3				9
Indianapolis Yellow	2				11
Improved Indianapolis Yellow	3				8
Indianapolis Yellow C.E.F.	3				9
Indianapolis Dark Yellow	3			9	
Indianapolis Gold	3			8	
Indianapolis Bronze	2				7
Indianapolis Dark Bronze	3				9
Indianapolis Apricot	3				8
Indianapolis Golden Bronze	3	9			

TABLE 1.—CHROMOSOME NUMBER OF CHRYSANTHEMUM VARIETIES—continued

Variety	Number of plants	Number of root tip cells							
		Chromosome number							
		54	*55*	*56*	*57*	*58*	*59*		
Queen Family									
Orchid Queen	5				15	1			
	1			6					
Jean Elizabeth	3				8				
Bronze Orchid Queen	3				12		1		
Crystal Queen	1					8			
Yellow Queen	2				1	11			
Dark Orchid Queen	4					18			
Lavender Queen	3					8			
	1						6		
		58	*59*	*60*	*61*	*62*	*63*	*64*	*65*
Pockett Family									
Thomas W. Pockett	5	24		1					
Louisa Pockett	3				11				
Yellow Pockett	1				6				
Turner Family									
William Turner	4			1	12	3			
Yellow Turner	1			12					
Bronze Turner	1		1	4					
Eva Turner	2						1	9	1

Indianapolis Pink, the original member of the Indianapolis family, was bred by Baur-Steinkamp of Indianapolis, Indiana. Figure 4 shows the derivation of eleven sports, all of which differ in flower colour except Improved White, a morphological variant. Indianapolis Yellow is a lemon yellow, Improved Yellow is a light golden yellow, Yellow C.E.F. is darker gold than Indianapolis Gold and is distinguished by its less vigorous growth, smaller leaves, and later flowering date. Two changes in chromosome number occur in the series.

Orchid Queen, the original variety of the Queen family, was also bred by Baur-Steinkamp. Figure 4 shows the origin of six colour sports, three of which differ in chromosome number from their immediate vegetative parents. Of the two white varieties, Crystal Queen ($2n = 58$) has a more compact inflorescence than Jean Elizabeth ($2n = 57$). The earlier report of $2n = 57$ for Dark Pink Orchid Queen (7) is based on plants later identified as Orchid Queen. Differences in chromosome number which were not accompanied by visible phenotypic changes were encountered in the Queen family. One of the six plants of Orchid Queen had $2n = 56$, whereas the others had $2n = 57$. Similarly, one of the four plants of Lavender Queen had $2n = 59$ instead of $2n = 58$ (Table 1). Therefore, changes in chromosome numbers are not necessarily associated with changes in flower colour.

The large-flowered, exhibition type Pockett varieties were produced in Australia. The white Louisa Pockett sported from the seedling Yellow Pockett with no change in chromosome number (2n = 61). The origin of pink Thomas W. Pockett (2n = 58) is unknown.

Both Yellow Turner and Bronze Turner (2n = 60) sported from the white William Turner (2n = 61). The origin of dark bronze Eva Turner (2n = 64) is unknown. Possibly it is unrelated to Yellow and Bronze because the form of its flower head is quite different. The Turners are large-flowered Australian exhibition types.

Chromosome Number Variation Within Families

The investigation of sports of known vegetative origin permits an estimate of the frequency with which sporting was associated with changes in chromosome number. Published data on this part of the problem are restricted to the pedigree of the Favorite family (3) which shows that six of the seven sports have changed chromosome numbers.

In the authors' material, the chromosome number of the immediate vegetative parent is known for 38 sports. Twenty-eight sports have the same number as the varieties from which they sported, three have a higher, and seven a lower number. That is, sporting was accompanied by gain or loss of a few chromosomes in 26.3 per cent of the cases studied.

Four sports, whose precise origins are unknown, are not included in the above estimate. At least one of the two Bulkeley sports differs in chromosome number from the original Mrs. Morgan G. Bulkeley. In addition, Eva Turner and Thomas W. Pockett differ in chromosome number from the other members of their families. Thus it is probable that 13 out of 41 sports (31.8 per cent) have chromosome numbers different from those of the varieties from which they sported. It cannot be directly proved that the changed phenotype of the sport is a result of the changed chromosome number. Indeed, two plants of the Queen family with changed chromosome numbers showed no change in flower colour. However, it is reasonable to assume a causal relationship in at least some of the sports.

Chromosome Number Variation Within Individuals

Dowrick (3) observed variations in chromosome number between cells of a single plant in 20 of the 65 varieties he examined. He postulated that a cell with a different number could give rise to a sport if its cell lineage

TABLE 2.—FREQUENCY OF ABNORMAL MITOTIC DIVISIONS IN CHRYSANTHEMUM ROOT TIPS

Variety	Normal divisions	Metaphase laggards	Telophase laggards	Telophase bridges
Indianapolis Pink	390	1	1	0
Indianapolis White	522	1	4	2
Indianapolis Bronze	1087	9	1	2
Indianapolis Yellow	453	0	0	0
Thomas W. Pockett	359	3	2	0
Louisa Pockett	434	0	3	0
Total	3245	14	11	4

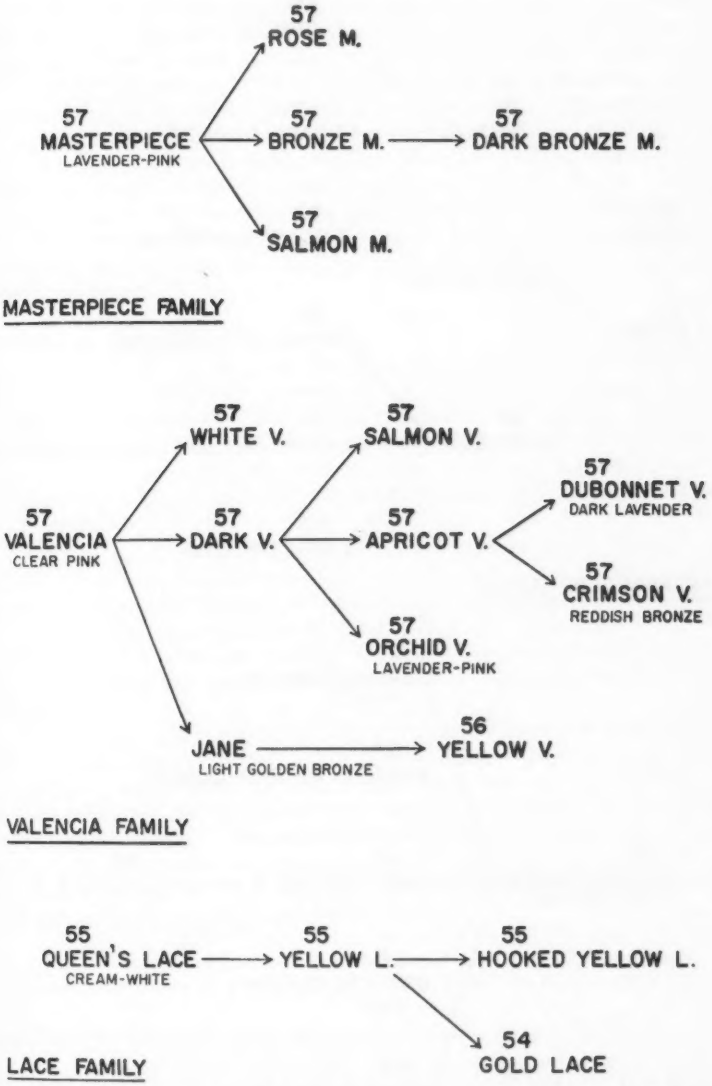

FIGURE 3. Pedigrees of the Masterpiece, Valencia and Lace 'families' of chrysanthemum sports showing the chromosome numbers and flower colour when the colour is not indicated by the variety name.

formed a chimera from which a branch with changed phenotype later arose. Variation of chromosome numbers within individual plants was confirmed in our study. It was found in 8 of the 51 varieties examined (Table 1) and was especially pronounced in the Queen and Turner families.

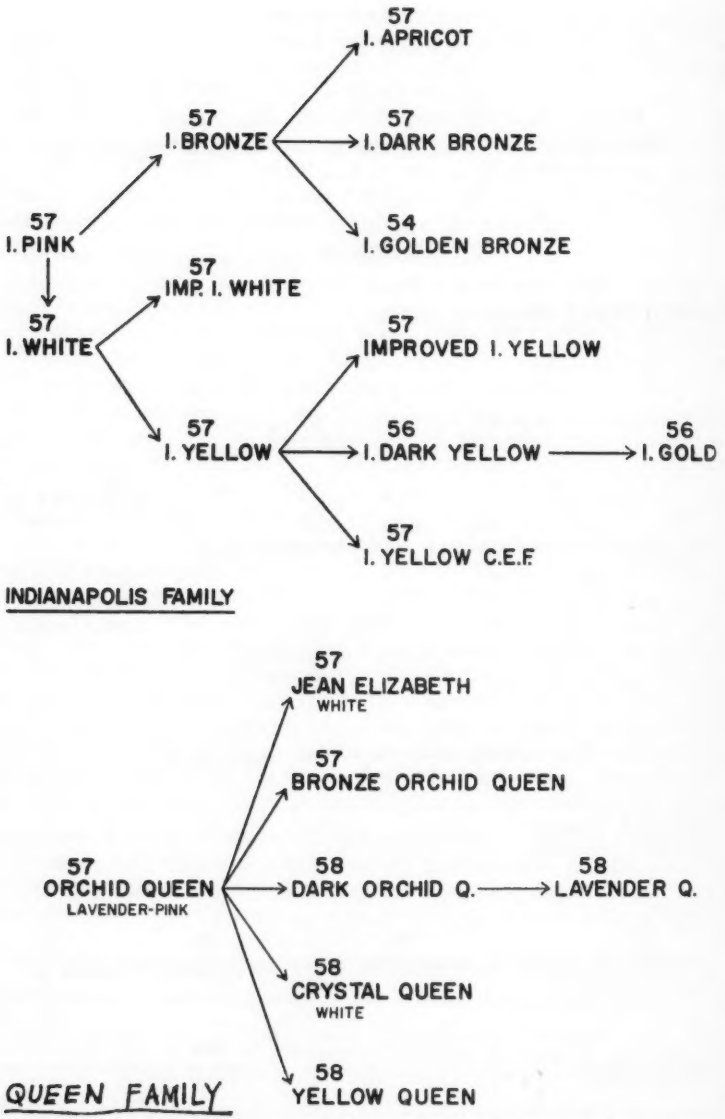

FIGURE 4. Pedigrees of the Indianapolis and Queen 'families' of chrysanthemum sports showing the chromosome numbers.

Mitotic Irregularities

Dowrick (3) observed abnormal mitotic divisions in chrysanthemum stem tips at a frequency of 1.11 per cent. These irregularities were thought to account for the chromosome number variation within individual plants.

Table 2 shows that similar phenomena were found in our material when the root tips were fixed and stained without pre-treatment with colchicine. Twenty-nine irregular divisions were found in 3274 cells, a frequency of 0.89 per cent. This high rate of irregular division can account for the changes in chromosome number associated with sporting. In addition, the formation and subsequent unequal breakage of bridges may result in a rearrangement, or a change in amount of chromosome material without necessarily changing the chromosome number (Figure 2). Possibly the very short chromosome which was observed in the Lace family resulted from this process. Shimotomai (5) reported that two Japanese varieties have fragment chromosomes, and Dowrick (3) found one in the English variety Turbulent.

The Problem of Periclinal Chimeras

Since only 30 per cent of the cases of sporting in our material are associated with changes in chromosome number, to what causes may the remainder be attributed? Doubtless, chromosome breakage with subsequent loss of fragments, and gene mutation, can result in different phenotypes without changing the chromosome number. In addition, two varieties each with, for example, 57 chromosomes, need not have the same 57 chromosomes.

Another possibility, which Anderson (1) pointed out in 1935, is that some of the sports are periclinal chimeras with the sported tissues restricted to the outer layers of the stem, whereas the internal tissue remains unchanged. Recent genetic studies by Mehlquist *et al.* (4) have shown that four carnation sports from the variety William Sim are periclinal chimeras, but the polyploid and aneuploid nature of our material precluded a similar analysis.

As pointed out by Dowrick, root tip chromosome counts may not detect chromosome number changes involving only the outer layers. Adventitious roots from chrysanthemum stem cuttings are derived from internal tissue (6) and therefore would retain the chromosome complement of the parent variety. The authors attempted to overcome this difficulty by obtaining chromosome counts from developing petals. Unfortunately the petal cells were so small that spreading of the chromosomes was hindered and accurate counts could not be made.

TABLE 3.—RESULTS OF FIVE HOT WATER TREATMENTS ON CHRYSANTHEMUM CUTTINGS

Treatment	Water temp. °C.	Length of treatment (min.)	No. of plants treated	No. of plants killed	Terminal bud killed	Terminal bud alive
A	40	20	64	0	1	63
B	40	40	64	0	42	22
C	45	10	64	8	56	0
D	45	20	64	11	53	0
E	50	10	64	49	15	0

TABLE 4.—RELATIONSHIP BETWEEN INFLORESCENCE SIZE AND CHROMOSOME NUMBER IN JAPANESE AND ENGLISH CHRYSANTHEMUM VARIETIES*

Inflorescence diameter	No. of varieties	Chromosome number distribution	
		Mode	Range
Japanese varieties			
less than 9 cm.	20	54	53–55
over 18 cm.	40	60	53–67
English varieties			
less than 12 cm.	33	54	47–56
12-20 cm.	18	56	54–57
over 20 cm.	14	61	56–63

*After Dowrick (3).

TABLE 5.—FREQUENCY DISTRIBUTION OF CHRYSANTHEMUM VARIETIES ACCORDING TO CHROMOSOME NUMBER AND INFLORESCENCE SIZE

Size class	Chromosome number								Total
	54	55	56	57	58	60	61	64	
Small	1	2	3	13					19
Medium	2	3	4	12	4				25
Large					1	2	3	1	7
Total	3	5	7	25	5	2	3	1	51

Another approach to the problem was suggested by the report (3) of a grower that hot water treatment of a chrysanthemum variety at 40° C. for 20 minutes, to control eelworms, resulted in 20 per cent sports. Possibly the treatment led to replacement of the epidermis by the inner tissue, and thus the mutated parts were removed.

Accordingly four varieties, Indianapolis Pink, Bronze, White and Yellow, were subjected to hot water treatments. These four are closely related (Figure 4) and have the same chromosome number, so that chimeras were suspected. Rooted cuttings, 10 to 15 cm. long, were used. The top 7 to 12 cm. of each plant was plunged into the hot water, leaving the roots untreated. Table 3 gives the five hot water treatments. Sixteen plants of each variety were used for each treatment and 18 untreated plants of each variety were grown for controls.

The most severe treatment (E, Table 3) killed a large proportion of the plants. Treatments B, C and D killed the terminal bud of most plants; the leaves were more or less injured, depending on the severity of the treatment, but new shoots appeared from the lateral buds. The weakest treatment, A, caused little injury to any part of the plant. All

surviving plants were flowered during the winter and spring of 1957. Plants which had their terminal buds killed were flowered from treated lateral buds. However, no sports were detected; the flowers were all true to type.

Thus the hypothesis of a chimeral constitution of these varieties is not confirmed. On the other hand, it cannot be disproved by the negative results of this experiment.

Relation Between Chromosome Number and Inflorescence Size

The work of Shimotomai (5) on Japanese chrysanthemum varieties and of Dowrick (3) on English varieties showed a positive correlation between chromosome number and inflorescence size, with a remarkable agreement between material from the two areas (Table 4).

It is difficult to compare the inflorescence size in chrysanthemums because this character varies with cultural practice. The comparisons attempted in the following are based on the usual cultural practice for each of our varieties. Probably the four families, Bulkeley, Masterpiece, Shasta and Valencia, with inflorescence diameters of 5-10 cm., are equivalent to Dowrick's smallest class. Members of the Lace family have a different type of inflorescence from the others, but probably can be included with the News, Indianapolis and Queen families in a medium size class with inflorescences between 13 and 18 cm. in diameter. Only the two Australian families, Turner and Pockett, are equivalent to the large class of Shimotomai and Dowrick.

Table 5 shows our findings on the frequency distribution of the several chromosome numbers in varieties belonging to the three inflorescence size classes. The distributions within the small and medium classes are essentially alike. Except that the medium class has four varieties with $2n = 58$, there is little indication that medium-sized varieties tend to have higher chromosome numbers than the smaller varieties.

Also noteworthy are the higher chromosome numbers of our small and medium varieties, compared with the results of Shimotomai and Dowrick (Table 4). Instead of a mode of $2n = 54$, the most frequent number in our material is $2n = 57$. In part, this may reflect sampling, because the Valencia and Indianapolis families contain 17 of the varieties with $2n = 57$ and the Masterpiece and Queen families contribute the remainder. However, the scarcity of varieties with $2n = 54$ in our material contrasts with the findings on Japanese and English varieties.

As a further check on the chromosome number of varieties with small inflorescences, five additional varieties were studied. The three pompon varieties, Pinocchio (diam. 1.8 cm.; $2n = 55$), Judith Anderson (diam. 2 cm.; $2n = 53$) and Yellow Fellow (diam. 3 cm.; $2n = 54$), and the two related singles, White Cascade and Jane Harte (both with diam. 4 cm.; $2n = 45$), agreed with the findings on Japanese and English varieties.

Similarly, the higher chromosome numbers found in the Turner and Pockett families agree with the Japanese and English results for large varieties. This points to a fundamental genetic difference between varieties belonging to different size classes but it is not known whether the

increased size results from a higher chromosome number *per se*, or whether the chromosome number differences among the size classes reflect differences in ancestry and, consequently, qualitative genetic differences.

ACKNOWLEDGEMENTS

We are indebted to W. E. Duffett, of Yoder Brothers Inc., Barberton, Ohio, who provided most of the information on the pedigrees of the varieties studied, and to his company for supplying gratis much of the material. A. P. Chan, Head, Floriculture Section, Horticulture Division, Canada Department of Agriculture, generously checked the trueness to type of each variety and contributed other valuable assistance.

REFERENCES

1. Anderson, C. Sporting of the chrysanthemum. Missouri Botan. Gard. Bull. 23: 161-163. 1935.
2. Debuisson, J. Nos chrysanthèmes: leur origine; leur nombre chromosomique. Bull. horticole 11:168-170. 1956.
3. Dowrick, G. J. The chromosomes of *Chrysanthemum*. II: Garden varieties. Heredity 7:59-72. 1953.
4. Mehlquist, G. A. L., D. Ober, and Y. Sagawa. Somatic mutations in the carnation, *Dianthus caryophyllus* L. Proc. Natl. Acad. Sci. 40:432-436. 1954.
5. Shimotomai, N. Zur Karyogenetik der Gattung *Chrysanthemum*. J. Sci. Hiroshima Univ. Ser. B., Div. 2, 2:1-100. 1933.
6. Stangler, B. B. Origin and development of adventitious roots in stem cuttings of chrysanthemum, carnation and rose. Cornell Univ. Agr. Expt. Sta. Memoir 342:1-24. 1956.
7. Walker, G. W. R. Chromosome numbers in chrysanthemum sports. Canada Dept. Agr., Hort. Div., Prog. Rept. 1949-53, pp. 69-70. 1955.
8. Wasscher, J. The importance of sports in some florist's flowers. Euphytica 5:163-170. 1956.

STUDIES ON SEED DORMANCY, PLANT DEVELOPMENT, AND CHEMICAL CONTROL OF TARTARY BUCKWHEAT (*FAGOPYRUM TATARICUM* (L.) GAERTN.).

I. SEED DORMANCY[1]

WILLIAM H. VANDEN BORN[2] AND WILLIAM G. CORNS[3]

University of Alberta, Edmonton, Alberta

[Received for publication April 10, 1958]

ABSTRACT

Effects of various physical, chemical, and storage treatments on dormancy of seeds of the noxious weed Tartary buckwheat (*Fagopyrum tataricum*) were studied. The dormancy is apparently not caused by any one single factor, such as impermeability of the seed coat to water suggested by earlier work. The seed coat did not prevent the entry of water into dormant seeds. Complete removal of both pericarp and seed coat resulted in a small increase in percentage germination of fresh seeds. There was no evidence of the presence of a growth-inhibiting substance. Chemical treatments were not effective in overcoming dormancy. Gibberellin improved the germination of partially after-ripened seeds, but not of fully dormant seeds. Newly mature seeds planted in the field immediately after collection failed to produce seedlings during that year. Similar seeds lost their dormancy in approximately 6 months during dry refrigeration at 2°-3°C., and in 4-5 weeks during dry storage at room temperature. Higher temperatures accelerated the process of after-ripening, to a maximum at approximately 80°C. Fully dormant seeds exposed to this temperature for 24-48 hours were able to germinate immediately afterwards. Relationships between moisture content, temperature, and germination are discussed.

INTRODUCTION

Among the weed problems in Alberta and other parts of the Prairie Provinces, Tartary buckwheat (*Fagopyrum tataricum* (L.) Gaertn.), a prohibited noxious weed, has assumed increasing importance in recent years, particularly because of its resistance to chemicals used in present-day weed control methods, and the difficulty of separating its seeds from grain.

Basic to the problem of attempting to develop more satisfactory methods for the control of this weed is an understanding of seed dormancy and seed germination, and of characteristics of growth and development of the species as affected by various treatments and environmental conditions.

According to Crocker (3), seed dormancy generally results from the inhibition of one or more of the processes preceding or accompanying germination. In many seeds the seed coat plays an important part in causing dormancy. The seed coat may prevent the entry of water (12) or oxygen (11), may contain a growth-inhibiting substance (7), or may prevent germination by "mechanical restraint" (4).

---

[1] Paper based on M.Sc. thesis of the senior author, Division of Crop Ecology, University of Alberta, Edmonton. 1958.
[2] Graduate Assistant (now at Petawawa Forest Experiment Station, Chalk River, Ont.).
[3] Professor of Crop Ecology.

Methods of overcoming seed dormancy are varied in nature, and generally depend on the particular type of dormancy involved (3). In seeds of the majority of species, dormancy may be overcome by a period of after-ripening, whether this be in dry storage at room temperature (10, 12), or at low temperature under moist condition (5). Germination of freshly harvested seeds of various species has been improved by heat treatment (6, 9), by chemical or mechanical scarification (6, 12), or by removal of seed coverings (12).

With dormant seeds of Tartary buckwheat, Cormack (1) found that removal of the pericarp and seed coat resulted in almost 100 per cent germination within 1 to 3 days. He suggested that the seed coat, which is heavily cutimized, is almost impervious to water, and possibly is responsible for dormancy of the seed. This view has been explored further in the current work, and considerable emphasis has been placed on certain innovations of procedure in studying effects of temperature and moisture on the after-ripening process.

MATERIALS AND METHODS

Seed Sources and Germination Tests

Tartary buckwheat screenings were obtained from a seed-cleaning plant at Vegreville, Alberta, in 1956. Plants grown from samples of this material in the field or in the greenhouse at Edmonton produced the seed used in subsequent germination tests. Where mature seeds were used, these seeds were collected when "newly mature," i.e., shortly after their colour had changed from green to that of fully mature seed.

Unless stated otherwise, all germination tests were made on duplicate samples of 50 seeds each, between folded moist paper towels, in a dark germinating cabinet at 20°C. The seeds were treated with dry Orthocide protectant prior to the germination test. Germinated seeds were counted, and removed from the germinator, at 3 and 7 days after the beginning of the test.

Imbibition of Water

The progress of water imbibition in dormant and non-dormant seeds was determined from the increase in weight of duplicate 100- or 200-seed samples, soaked in distilled water for different intervals. The seeds were weighed after excess moisture was removed by suction and by drying on paper towels for 15 minutes.

For moisture determinations, duplicate samples of approximately 100 seeds each were ground in a Wiley mill through a 20-mesh screen, weighed, and dried at 105° C. for 1 hour, following which they were weighed again, and the moisture content was calculated. For moisture contents of soaked samples, whole seeds were dried for 16 to 20 hours at 105° C. All moisture contents were calculated on the oven-dry weight basis.

To obtain seeds with different moisture contents, seeds were soaked in water and redried, or small volumes of water were added to seed samples whose weight and initial moisture content were known. Calculated levels were confirmed by actual moisture determinations.

Chemical Treatments

Chemicals used included concentrated sulphuric acid, 95 per cent ethyl alcohol, and gibberellin (10-1,000 p.p.m. acid equivalent). Seeds were immersed in the solution used for periods varying from 2 minutes to 24 hours, following which they were rinsed with water (except in the case of gibberellin), and placed in the germinator.

Natural Growth-Inhibitors

Tests for the presence of growth-inhibiting substances were carried out with extracts obtained by soaking the intact or ground seeds in water, by extraction with ethyl alcohol, or by expressing the juice from water-soaked seeds in a Carver hydraulic press.

The effects of the various extracts on growth of seedlings were observed in tests in which two ml. of each was used to moisten the filter paper in a dish containing 25 Tartary buckwheat seeds, held at 20° C. for 7 days in a humid growth cabinet.

RESULTS AND CONCLUSIONS

Imbibition of Water

If the seed coat is impermeable to water, and thus prevents germination—a possibility suggested by Cormack (1)—pricking a hole through both pericarp and seed coat, or cutting a thin slice off the base of the seed, should allow sufficient water to enter the seed, thus overcoming the cause of dormancy. Table 1 shows the results of two experiments in which the above treatments were included. It was evident that complete removal of both pericarp and seed coat resulted in an increase in germination of fresh seeds, but that partial removal of these structures did not overcome dormancy.

In two other experiments involving small numbers of seeds which had failed to sprout in the germinator, removal of both pericarp and seed coat resulted in up to 50 per cent germination. Non-dormant seeds did not suffer any serious injury from similar treatments.

TABLE 1.—PERCENTAGE GERMINATION OF DORMANT AND NON-DORMANT SEEDS OF TARTARY BUCKWHEAT, OF WHICH THE PERICARP AND SEED COAT WERE PARTLY OR ENTIRELY REMOVED

Treatment	Germination, %		
	Fresh seeds	Seeds in refrigerator for 6 weeks	Non-dormant seeds
None—seeds entire	0 (0)*	4	86
Pericarp removed	0 (3)	4	100
Pericarp and seed coat removed	10 (13)	20	—
Seeds pinpricked	0 (1)	6	90
Slice cut from base of seed	0 (5)	4	100
	no significant difference	—	—

* % germination after 14 days.

TABLE 2.—PERCENTAGE INCREASE IN WEIGHT OF DORMANT AND NON-DORMANT SEEDS OF TARTARY BUCKWHEAT AFTER SOAKING IN WATER

Hours soaked	Increase in weight, %			
	Experiment I		Experiment II	
	Dormant	Non-dormant	Dormant	Non-dormant
½	19.6	31.8	26.3	28.9
1	22.0	33.6	28.6	31.1
2	26.6	38.1	32.1	35.5
4	32.0	40.2	37.6	39.9
8	37.1	42.8	42.7	41.0
24	47.1	48.0	48.4	46.9
48	49.8	50.9	49.6	49.1
120	53.4	54.0	—	—
Initial % moisture	9.5	8.3	11.0	11.4

Table 2 shows the results of two experiments in which the amount of water taken up by imbibition was calculated as a percentage of the initial air-dry weight of the seed sample. Newly collected mature seeds were stored dry at room temperature for 12 and 5 days (Experiments I and II, respectively) in order to attain comparable initial moisture contents in dormant and non-dormant seeds.

A statistical analysis of the actual increases in weight in both experiments showed a significant interaction between soaking time and type of seeds used; the difference between dormant and non-dormant seeds was not significant. The significant interaction may be explained by the observation that, during the first half-hour, especially in Experiment I, the non-dormant seeds imbibed water much more quickly than did the dormant seeds, while the latter caught up again during the 8-24 hour soaking period. The seed coat apparently did not prevent the entry of water into dormant seeds.

Chemical Treatments

Dormancy in fresh seeds was not overcome by treatment with various chemicals causing scarification of the seed-surrounding structures or some physiological effect. Partially after-ripened seeds showed an increase in germination following soaking for 24 hours in an aqueous solution of gibberellin containing 1000 p.p.m. acid equivalent. Germination was increased from 5 per cent to 19 per cent in one case, and from 4 per cent to 32 per cent in another. Removal of part of the pericarp and seed coat to facilitate entry of the chemical did not improve the response to treatment with gibberellin.

Natural Growth-inhibitors

Lehmann (7) reported the presence of a water-soluble growth-inhibiting substance in the pericarp of seeds of *Fagopyrum esculentum*, which was extracted by soaking in water. To determine whether or not a similar substance was present in seeds of Tartary buckwheat, several experiments were carried out in which seeds of this species were germinated in extracts

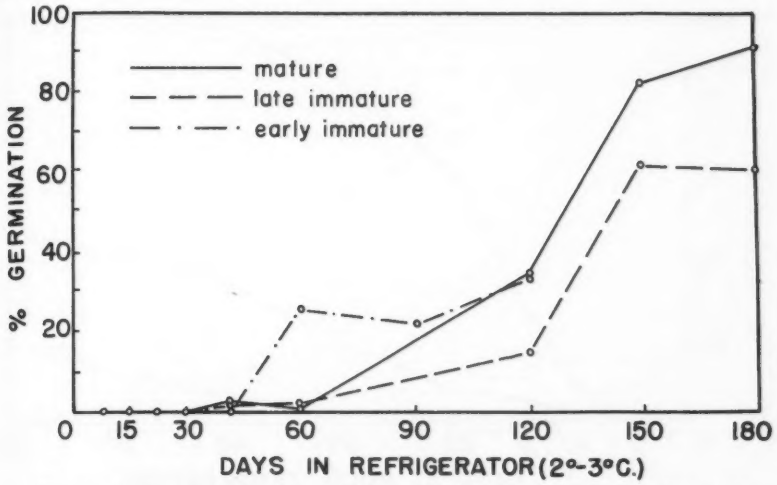

FIGURE 1.—Germination of fresh Tartary buckwheat seeds following dry storage in a refrigerator (2°-3° C.).

of both dormant and non-dormant seeds as outlined earlier. In no case did the results of these experiments indicate the presence of a growth-inhibiting substance which might be responsible for dormancy.

Germination Following Field-planting or Storage under Various Conditions

When mature or immature seeds were planted in the field immediately after being collected (1956 and 1957), no emergence took place during the same season. Of the fresh seeds planted during the late summer of both 1956 and 1957, 10 to 13 per cent produced seedlings the following spring.

Samples of seed collected during 1956 were stored dry at 2°-3° C. in a refrigerator, at room temperature on a laboratory bench, or at 40°C. in an electric oven. Figures 1, 2, and 3 show the results of germination of representative samples of mature and immature seed stored under the above conditions.

The after-ripening process took place much more quickly at a relatively high temperature than at a low temperature. Mature seeds, which required 5 to 6 months to after-ripen at refrigerator temperature, lost their dormancy in 2 weeks at 40° C. Immature seeds required a considerably longer period to after-ripen under similar conditions, and then did not attain as high a percentage germination as did the mature seeds. Seeds collected during 1957, and stored dry at room temperature or in the refrigerator for varying periods, yielded essentially the same results as did the 1956 seeds.

Seeds stored at 5° or 10°C. for periods up to 6 months, in waxed-paper containers filled with moist vermiculite, appeared to have the same degree of dormancy as freshly collected seeds, and had to be stored dry at room temperature for at least 4 weeks before the majority would germinate. Seeds kept saturated with moisture at room temperature similarly failed to after-ripen.

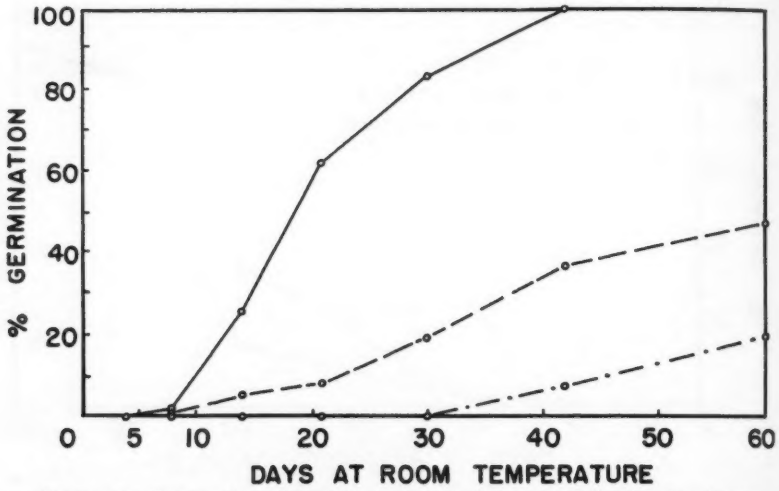

FIGURE 2.—Germination of fresh Tartary buckwheat seeds following dry storage at room temperature.

Subjecting mature dormant seeds to alternate wetting and drying in petri dishes did not break their dormancy. Alternating temperature treatments (20° to 30°C. or −20° to room temperature) were also ineffective in overcoming dormancy of the seeds. Seeds stored in an oxygen atmosphere under a bell jar did not after-ripen more quickly, and seeds stored in nitrogen lost their dormancy somewhat more slowly than seeds in air.

When dormant seeds, immediately or soon after being collected, were placed in glass tubes closed tightly with rubber stoppers, and kept at room temperature, they lost their dormancy much more quickly than did similar seeds kept in open containers (Table 3), possibly because the initial moisture content of the seeds in the closed tubes was maintained throughout the course of the experiment, while the moisture content of the seeds in the open containers soon fell below the optimum level for after-ripening. The optimum moisture level was in the range of approximately 15 to 20 per cent.

TABLE 3.—PERCENTAGE GERMINATION OF TARTARY BUCKWHEAT SEEDS AFTER STORAGE IN OPEN OR CLOSED CONTAINERS AT ROOM TEMPERATURE

Weeks stored	Germination %				
	Experiment I		Experiment II		
	Open	Closed	Open	Closed	Closed
0	2	2	2	0	0
1	6	32	1	2	2
2	8	45	0	41	1
3	19	99	11	100	2
4	50	100	—	—	—
5	72	100	—	—	—
Initial % moisture	—			21.8%	approx. 30%

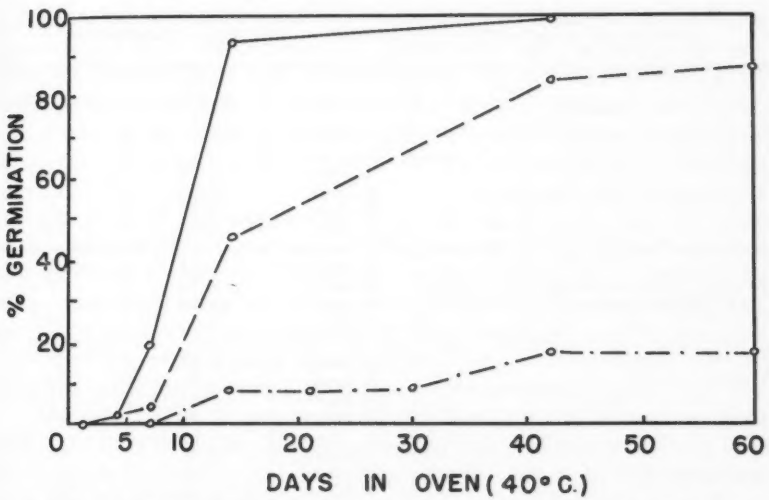

FIGURE 3.—Germination of fresh Tartary buckwheat seeds following dry storage in an electric oven (40° C.).

Statistical analysis of the data indicated a highly significant interaction between length of storage and method of storage. This substantiated the above conclusion that, under the conditions of the experiment, dormant seeds after-ripened much more quickly in tightly closed containers than in open ones.

High-Temperature Treatments

From the results obtained after storing seeds under different conditions it was evident that, during dry storage, seed dormancy was overcome much more quickly at a relatively high temperature than at a low temperature. Further experimentation indicated that relatively short exposures of the seeds to temperatures above 40°C. (the highest one used in the first series of experiments, Figure 3) were very effective in overcoming dormancy.

Beneficial effects of high temperature treatment in breaking dormancy of seeds were first observed when mature seeds of 38 per cent germination, which had partially after-ripened during 4 months' storage in the refrigerator, were dried at 80°C. for 1 to 24 hours. From 92 to 100 per cent of the seeds germinated after treatment for at least 2 hours.

Dormant seeds, unable to germinate after being stored in the refrigerator, or at room temperature, for varying periods following collection, showed essentially the same response to high temperature treatment. Results indicated that, the shorter the period of storage, the longer the exposure required at high temperature to attain comparable germination percentages. Heating seeds to 60°C. in stoppered glass vials was as effective as heating them to 80°C. in open containers in overcoming dormancy. In the closed vials the initial moisture content of the seeds was maintained throughout the course of the treatment. That the seeds were

TABLE 4.—MOISTURE CONTENT AND PERCENTAGE GERMINATION OF TARTARY BUCKWHEAT SEEDS AFTER VARIOUS HEATING AND DRYING TREATMENTS*

Treatment	Time	Moisture %	Germination %
Dry storage at room temperature	0 days	9.37	2
	14 days	8.38	15
	21 days	8.56	20
	28 days	8.83	81
Storage in desiccator with conc. H_2SO_4 at room temperature	7 days	4.21	4
	14 days	2.98	7
	21 days	2.44	11
	28 days	2.14	9
Heating to 70° C.	8 hours	3.62	14
	24 hours	2.66	30
	48 hours	2.33	77
	72 hours	2.32	90
Heating to 80° C.	8 hours	3.08	11
	24 hours	1.92	40
	48 hours	1.38	86
	72 hours	0.99	96

* Seed collected 3 days before the start of the experiment

not killed by the heat treatments was shown by storing the non-germinated seed dry at room temperature for 4 to 6 weeks, and then observing growth after placing them in the germinator again.

To distinguish further between the effects of heating and of loss of moisture, dormant seeds were dried in a desiccator containing a dish with concentrated sulphuric acid which had previously been boiled for 4 hours. Following the treatment both the moisture content and the percentage germination of the seed samples were determined (Table 4).

Statistical analysis of transformed data (angular transformation) showed a highly significant effect of treatment. It is evident from the data in Table 4 that increasing length of exposure to 70° or 80°C. resulted in significantly greater germination. Differences between corresponding treatments at 70°C. and 80°C. were not statistically significant in this experiment.

DISCUSSION

The inconsistency of some of the results of the present work in comparison with Cormack's findings (1) may perhaps be explained by the fact that the seed used by that worker had already after-ripened to some extent, while the material used by the authors was freshly collected, "newly mature" seed. Partial removal of seed coverings by dissection or by chemical scarification did not overcome dormancy of Tartary buckwheat seeds. Since the complete removal of these structures did improve germination, one might suggest the presence of a growth-inhibiting substance in the pericarp or seed coat, as has been shown in some other species (6, 7, 11). In the work reported here, however, the presence of such a substance

could not be demonstrated. The percentage germination of partially after-ripened seed was increased by gibberellin, but dormancy was not overcome by treatment with this substance. In this respect the results are comparable to those obtained by Corns (2) with seeds of vine maple and in unpublished work with some species of annual weeds. Apparently the gibberellin under certain circumstances partially counteracts inhibiting substances or processes.

The reduction in moisture content resulting from heating the seeds to high temperatures in open containers appeared to be of little importance in overcoming dormancy. There was no direct relationship between the process of after-ripening, and drying out of the seeds. The loss of dormancy was much more strongly influenced by heat treatment than by moisture content of the seeds, though there was evidence for an optimum moisture content for the after-ripening of seeds at room temperature.

The significance of some of these findings in weed control methods may become evident, for example, where fall tillage immediately following harvesting is practised. In a field infested with Tartary buckwheat many mature seeds of this species will be left on the ground when harvesting is completed. If the weather has been hot and dry for a few weeks, prior to and during harvesting, the majority of the seeds on the ground will have lost their dormancy, and the field may be tilled without much danger of burying dormant seeds in the soil. Under favourable temperature and moisture conditions following tillage, the majority of the seeds covered up will germinate, and emerging seedlings may be destroyed by further cultivation or by frost. If, on the other hand, the weather has been cold and wet, mature buckwheat seeds on the plant and on the soil surface will after-ripen very slowly. Immediate tillage will result in covering up these dormant seeds, and long periods may elapse before they after-ripen sufficiently to germinate and grow. The indication is, therefore, that under cold and wet conditions tillage should be delayed at least until the following spring, when the seeds may have had sufficient time to after-ripen.

ACKNOWLEDGEMENTS

The financial assistance of the National Research Council of Canada is gratefully acknowledged.

REFERENCES

1. Cormack, R. G. H. Notes on the germination of Tartary buckwheat. Sci. Agr. 32:170-172. 1952.
2. Corns, Wm. G. Some factors affecting the germination of the seed of vine maple (*Acer circinatum*). Research Rept. Natl. Weed Committee, Western Section, pp. 131-132. 1957.
3. Crocker, W. Mechanics of dormancy in seeds. Amer. J. Botany 3:99-120. 1916.
4. Crocker, W., and W. E. Davis. Delayed germination in *Alisma plantago*. Botan. Gaz. 58:285-321. 1914.
5. Davis, W. E. Primary dormancy, after-ripening, and the development of secondary dormancy in embryos of *Ambrosia trifida*. Contribs. Boyce Thompson Inst. 2:285-303. 1930.

6. Harrington, G. T. Forcing the germination of freshly harvested wheat and other cereals. J. Agr. Research 23:79-100. 1923.
7. Lehmann, W. Zur Keimungsphysiologie des Buchweizens. Landwirtsch. Jahrb. Schweiz 84:741-778. 1937.
8. Naylor, J. M., and L. A. Christie. The control of dormancy in wild oats. Proc. Natl. Weed Committee, Western Section 10:56-59. 1956.
9. Rincker, C. M. Effect of heat on impermeable seeds of alfalfa, sweet clover, and red clover. Agron. J. 46:247-250. 1954.
10. Stevens, O. A. Studies on wild buckwheat. N. Dakota Agr. College Bull. 346. 1947.
11. Thornton, N. C. Factors influencing germination and dormancy in cocklebur seeds. Contribs. Boyce Thompson Inst. 7:477-496. 1935.
12. Toole, E. H., *et al.* Physiology of seed germination. Ann. Rev. Plant Physiol. 7:299-324. 1956.

STUDIES ON SEED DORMANCY, PLANT DEVELOPMENT, AND CHEMICAL CONTROL OF TARTARY BUCKWHEAT (*FAGOPYRUM TATARICUM* (L.) GAERTN.).

II. GERMINATION, GROWTH, FLOWERING AND SEED PRODUCTION[1]

WILLIAM H. VANDEN BORN[2] AND WILLIAM G. CORNS[3]

University of Alberta, Edmonton, Alberta

[Received for publication April 10, 1958]

ABSTRACT

Seed germination, plant development, flowering and seed production of Tartary buckwheat (*Fagopyrum tataricum*) were observed under various environmental conditions. After-ripened seeds germinated over a wide range of temperatures under laboratory conditions, and in the field produced seedlings whenever tested during the growing season. Shoots were sent up from depths up to 6 inches. Flowering began 5 to 6 weeks after planting, and the first seeds matured 4 to 5 weeks later. Flowering and seed production continued until stopped by frost in the fall. Yields of vegetative matter and seed were recorded. Abnormal seeds produced by buckwheat plants treated with low volatile (LV) 2,4-D were as viable as were normal seeds, and when planted in the field the following year they produced plants which were normal in all respects.

INTRODUCTION

Available literature dealing specifically with the prohibited noxious weed Tartary buckwheat is very limited (2, 7), probably because the species is only of local importance as a weed in some areas (3), and as a cultivated crop in others (4, 5). Studies on seed dormancy of the species have been reported in Part I (9). In the present work, development of the seedling and later phases of growth were studied under various conditions.

MATERIALS AND METHODS

Triplicate 50-seed samples of after-ripened material were germinated on moist filter paper in petri dishes, or planted one-half inch deep in pots filled with soil, and kept at various temperatures (± 1°C.).

The relationship between depth of planting and emergence was investigated by planting triplicate or quadruplicate 25- or 50-seed samples at different depths in the field or in pots in the greenhouse, and observing the emergence of seedlings.

During almost the entire growing season in 1957, duplicate 100-seed samples were planted in the field at 2-week intervals, and a record was kept of the emergence of seedlings in order to determine if there was any periodicity in germination, or any time during which seeds would not germinate and produce seedlings.

---

[1] Paper based on M.Sc. thesis of the senior author, Division of Crop Ecology, University of Alberta, Edmonton, Alta. 1958.

[2] Graduate Assistant (now at Petawawa Forest Experimental Station, Chalk River, Ont.).

[3] Professor of Crop Ecology.

In the experiments in which the progress of flowering and seed production was investigated, Tartary buckwheat was seeded with a V-belt seeder in quadruplicate field plots approximately 11′ × 20′. One set of four plots was seeded on each of three dates in both years. Seeds in the two centre rows were counted (250 seeds per 20 feet); these rows were used for emergence counts and for determinations of yields in the fall.

To determine the progress of seed maturation field plots were seeded to Tartary buckwheat on three different dates in 1957. When seed production began, three plants were selected at random from each plot once a week, and all the seeds removed. The total number of seeds and the percentage mature seeds were then recorded.

The effects of spraying with 2,4-dichlorophenoxyacetic acid (2,4-D) on flowering, seed production, and seed viability were studied in an experiment in which quadruplicate 8′ × 10′ plots were seeded to Tartary buckwheat. The plants were sprayed with low volatile (LV) 2,4-D (Weedone LV4), using 40 gal./A. of solution. At the end of the growing season three rows from each plot were harvested for determinations of yield and detection of abnormalities present in the seed.

RESULTS AND CONCLUSIONS

Germination Temperature

The results of germination of Tartary buckwheat seeds at different temperatures are illustrated in Figure 1. At 38°C., the highest temperature used, some seeds germinated and grew until 5 days after the beginning of the test, after which time the sprouts died. The rate of elongation of germinating seedlings was relatively constant over the temperature range 20°-30°C. (Figure 2). At the lower temperatures, germination and subsequent elongation took place very slowly.

In the field, after-ripened seeds germinated and grew whenever tested during the growing season. It appears, therefore, that there is no period

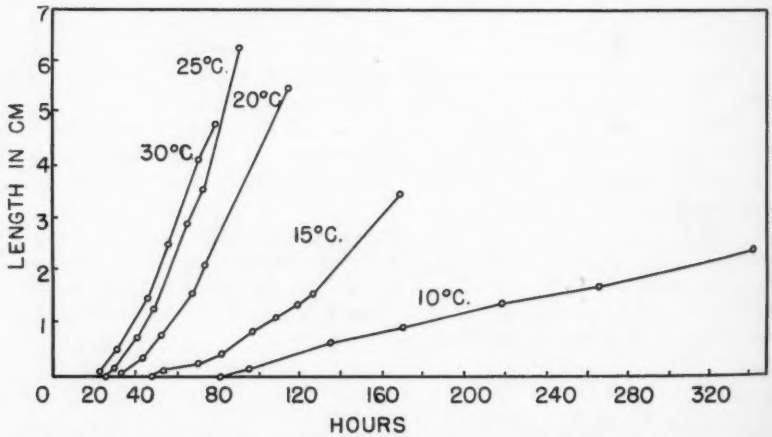

FIGURE 1.—Percentage germination or emergence of Tartary buckwheat seeds at different temperatures.

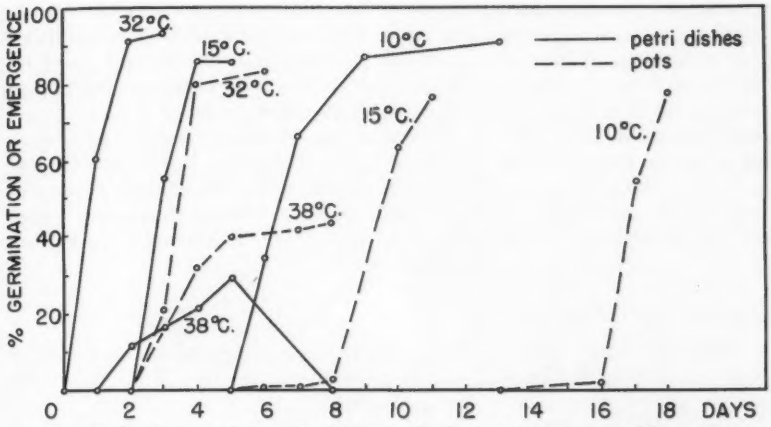

FIGURE 2.—Increase in length of Tartary buckwheat seedlings at different temperatures.

during the growing season sure to be free from the need for concern about control measures.

The period required to attain maximum germination increased with decreasing soil temperatures, i.e., when relatively low soil temperatures occur; for example, early in the spring and late in the fall, germination and growth take place very slowly. Thus, even if environmental conditions are favourable for after-ripening of the seeds (as discussed in Part I), there may be limitations to the effectiveness of subsequent tillage if there is not a continued period of reasonably warm weather for germination of the seed.

Emergence from Different Depths of Seeding

Results of two representative experiments dealing with depths of seeding are presented in Table I.

Among the results of the five experiments carried out there was considerable variation, expecially at the greater planting depths. In the pot

TABLE 1.—EMERGENCE OF TARTARY BUCKWHEAT SEEDLINGS FROM DIFFERENT DEPTHS IN THE SOIL

Planting depth	Field (planted July 6)		Greenhouse (pots)	
	Maximum % emergence	Days to maximum emergence	Maximum % emergence	Days to maximum emergence
1″	89	8	96	13
2″	85	10	88	13
3″	94	12	92	17
4″	70	14	92	17
5″	4	15	84	20
6″	0	—	42	23
8″	—	—	0	—

experiments, probably because of better aeration or otherwise more favourable conditions, emergence occurred from a greater depth than it did under field conditions. When, in one of the pot experiments, the soil was carefully washed away with a stream of water, it was found that the percentage germination at a depth of 6 inches was only slightly lower than at 1 or 2 inches below the soil surface. Many of the seedlings from 6 inches deep had come to within about 1 inch of the soil surface, but failed to grow the whole distance, presumably as a result of an insufficient supply of reserve food materials. The fact that some seedlings did emerge from this depth, however, makes doubtful the value of attempts to control Tartary buckwheat by deep cultivation.

Flowering and Seed Production

Data obtained during 1956 and 1957 from observations of flowering made on Tartary buckwheat plants growing in the field, and from yield determinations, are summarized in Table 2.

Flowering began 5 to 6 weeks after planting, and the first seeds matured 4 to 5 weeks later, or a total of 9 to 11 weeks after planting. The data obtained for "days to first flower" and "days to first mature seed" correspond rather closely to those reported by Quisenberry and Taylor (5) for *Fagopyrum esculentum*. In both years flower and seed production was stopped by frost during the latter half of September.

With a later planting date the time from planting to the first mature seed became shorter (Table 2). This observation can be explained by the findings of Skok and Scully (7), who reported that short photoperiods promoted floral development and fruit production on Tartary buckwheat plants. Visual observations made in the present study also substantiated the conclusion of these workers that the shorter photoperiods occurring later in the summer favoured lateral shoot development over elongation of the main axis. Plants grown from seed planted at the later dates were considerably more bushy than those from earlier plantings.

TABLE 2.—PROGRESS OF FLOWERING AND SEED PRODUCTION OF TARTARY BUCKWHEAT PLANTS

	Planting date					
	1956			1957		
	May 18	June 21	July 19	May 17	June 8	July 1
Maximum % emergence	80	87	91	—	82	96
Days to maximum emergence	11	13	7	—	14	10
Days to first flower	39	37	—	46	35	37
Days to first immature seed	53	50	42	54	45	42
Days to first mature seed	77	70	62	79	68	62
Days to harvest (Sept. 17-20)	122	88	63	—	101	78
Lb./A. dry vegetative matter	3902	2670	2977	—	—	—
Lb./A. seed yield	5093	2516	704	—	2049	1360
% Mature seed	74.8	58.6	8.7	—	—	—

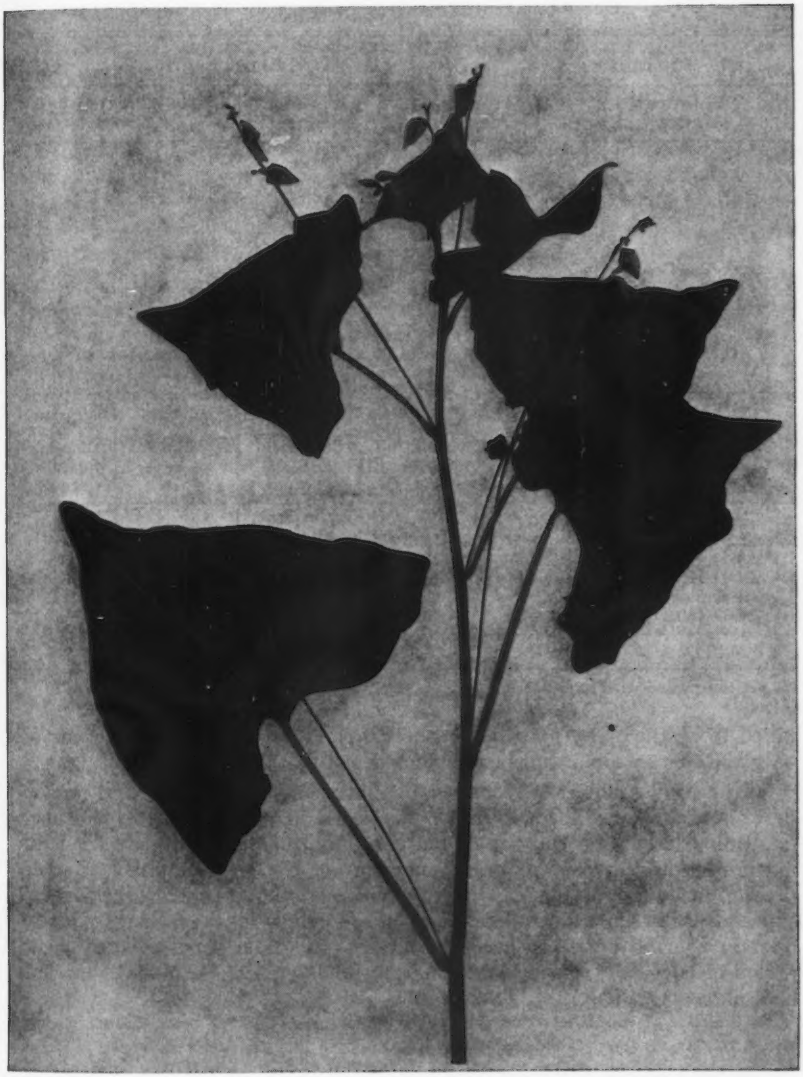

FIGURE 3.—Branch of Tartary buckwheat plant with flowers, immature seeds and mature seeds.

Because of the indeterminate flowering habit of Tartary buckwheat (4, 5), flowers, immature seed and mature seed may all be present on the same plant at any given time during at least part of its growth period (Figure 3). During this period the percentage of mature seeds on the plant gradually increases (Table 3). Since the latest planting (July 16)

TABLE 3.—PROGRESS OF SEED MATURATION ON TARTARY BUCKWHEAT PLANTS

Planted June 8		Planted July 1	
Days after planting	% Mature seeds	Days after planting	% Mature seeds
61	0	59	0
68	1.1	66	0.7
75	4.8	73	5.9
82	11.7	78	20.8
89	20.8	—	—
96	52.0	—	—
101	65.0	—	—

TABLE 4.—SEED PRODUCTION OF TARTARY BUCKWHEAT PLANTS TREATED WITH LV 2,4-D AT TWO STAGES OF DEVELOPMENT (VEGETATIVE AND EARLY FLOWERING)

Treatment	Stage	Dry weight vegetative matter lb./A.	Seed yield lb./A.	% Mature seeds	% Abnormal mature seeds*
Check	—	3488	2966	76.1	0.4
LV 2,4-D 6 oz/A	1	2592	2032	73.6	6.4
LV 2,4-D 12 oz/A	1	2384	1400	57.0	4.9
LV 2,4-D 6 oz/A	2	2592	2142	77.0	10.0
LV 2,4-D 12 oz/A	2	2656	1949	72.9	9.7
L.S.D. 5%		320	251	7.0	3.7

* Based on total number of mature seeds

failed to produce any mature seed before the first fall frost, the results of only the first two plantings are included in this table.

The total number of seeds per plant varied considerably, and for the first planting ranged from 400 at 68 days to 1100 at 89 days after planting, depending largely on the size of the individual plant. The percentage of mature seeds appeared to be independent of the total number of seeds present on a plant. Given a longer growing period (cut short in the writers' experiment by cutworms necessitating re-seeding in the spring, and by frost in the fall of 1957), seed maturation can take place over a longer period of time, and a percentage mature seeds greater than that reported here may be attained (cf. Table 2).

Effects of LV 2,4-D on Seed Production

Tartary buckwheat plants at two stages of development were treated with LV2,4-D: at stage 1 the plants were 4 inches high and had six to seven leaves; at stage 2 the plants were 10 to 12 inches tall, and some flowers and a large number of flower buds were present. The buckwheat plants were far enough advanced in growth stage to not be killed by any of the treatments, though growth was slowed down or stopped entirely for at least a short period following the application of LV2,4-D. Records made at harvest time are presented in Table 4.

Treated plants yielded less vegetative matter and seed than did untreated plants, and produced a number of seeds of abnormal appearance (smaller than normal seeds, and strongly flattened longitudinally). Treatment at stage 1 was most effective in stunting the plants, but similar treatments at stage 2 resulted in the production of almost twice as great a percentage of abnormal seeds. This result was not surprising, since a large number of flower buds were present on the plants at the time the second treatment was applied. The percentage of abnormal seeds was relatively low because new shoots, developed after the plants had recovered from the spraying treatment, produced normal flowers and seeds.

Results of periodic germination tests indicated that in dry storage at room temperature the abnormal seeds after-ripened somewhat more slowly than did normal seeds, but that viability was equally great in both. After 5 weeks of storage both normal and abnormal seeds from all treatments germinated 92-99 per cent. When planted in the field, abnormal-appearing seeds developed into plants which were normal in all respects. The results, therefore, did not support the possibility of effecting the production of non-viable abnormal seeds as a useful agronomic practice, by treating the plants with hormone-type herbicides at the flower-bud or flowering stage.

ACKNOWLEDGEMENTS

The financial assistance of the National Research Council is gratefully acknowledged.

Mike Ostafichuk prepared the photographs.

REFERENCES

1. Chepil, W. S. Germination of weed seeds. I. Longevity, periodicity of germination, and vitality of seeds in cultivated soil. Sci. Agr. 26:307-346. 1946.
2. Cormack, R. G. H. Notes on the germination of Tartary buckwheat. Sci. Agr. 32: 170-172. 1952.
3. Frankton, C. Weeds of Canada. Publ. 948, Canada Dept. Agr., Ottawa. 1955.
4. Martin, J. H., and W. H. Leonard. Principles of field crop production. MacMillan Co., New York, N.Y. 1949.
5. Quisenberry, K. S., and J. W. Taylor. Growing buckwheat. Bull. 1835, U.S. Dept. Agr., Washington, D.C. 1939.
6. Rice, E. L. Effects of plant growth regulators on flowering in several crop plants. Botan. Gaz. 112:207-213. 1950.
7. Skok, J., and N. J. Scully. Nature of the photoperiodic responses of buckwheat. Botan. Gaz. 117:134-141. 1955.
8. Steinbauer, G. P., *et al.* A study of methods for obtaining laboratory germination of certain weed seeds. Proc. Assoc. Offic. Seed Analysts 45:48-52. 1955.
9. Vanden Born, William H., and William G. Corns. Studies on seed dormancy, plant development and chemical control of Tartary buckwheat (*Fagopyrum tataricum* (L.) Gaertn.) I. Seed dormancy. Can. J. Plant Science 38:357-366. 1958.

NOTE ON A MODIFIED ELECTRIC BIRD PERCH FOR PROTECTING CROPS

The protection of seed crops from birds is a major problem at the Experimental Farm, Saanichton, British Columbia. Each year California purple finches and English sparrows destroy the early maturing winter oat varieties and, later in the season, goldfinches feed on lettuce and radish crops, causing serious loss of seed in small plots.

Many crop protection methods have been tested. Scarecrows, flashing objects, repellent sprays and explosive-type noisemakers were ineffective. The only effective control was to cage the plot area with fine mesh fishnet to exclude the birds. This method was expensive and limited the size of the experiments.

In 1957, an electric bird-scaring apparatus similar to that reported by Pfeifer (1) gave excellent control of California purple finches and English sparrows in fall-planted cereal plots. For the first time early varieties of winter oats were grown in an open field without serious damage by birds. However, later in the season this device was not as effective in protecting lettuce and radish seed crops against goldfinches. It was noticed that these birds would light on one wire of the perch and often remain unshocked. By modifying the bird perch, this difficulty was overcome and the birds were positively shocked and frightened away each time they used the perch.

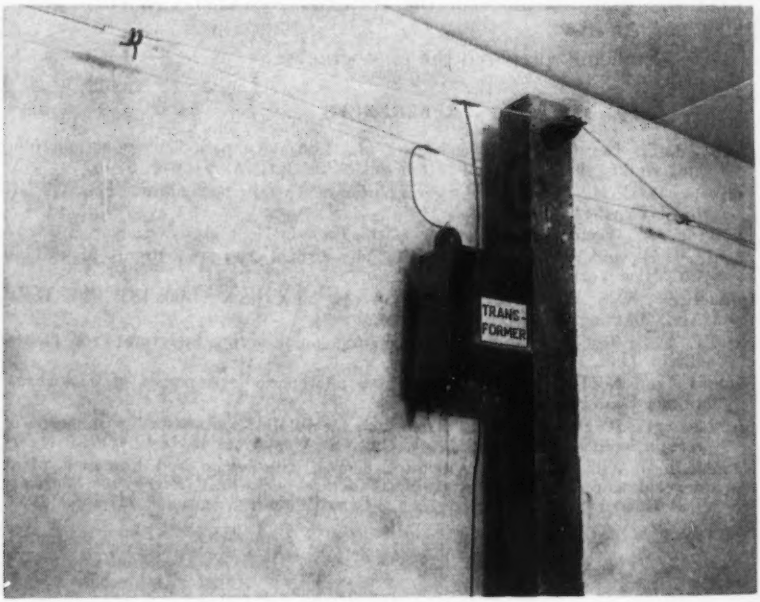

FIGURE 1. Photo showing location of transformer on 20-foot pole, wiring of transformer to bird perch, method of attaching bird perch wires to insulators on poles, and method of using porcelain tube insulators to form the narrow-spaced bird perch.

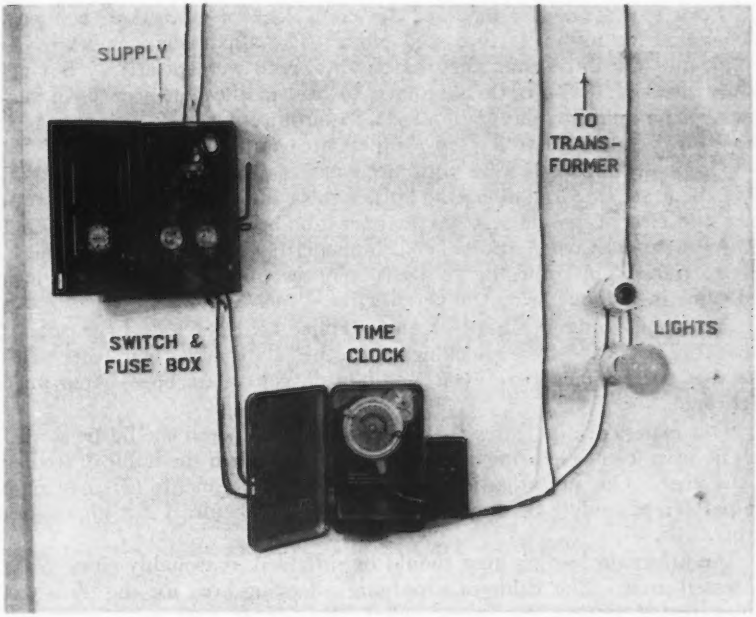

FIGURE 2. Photo showing wiring of the 110-volt primary circuit. From the source the current travels through the main switch, time clock and light-sockets to the primary terminals of the transformer.

The modified bird perch was erected as follows:

1) The bird perch consisted of two cables of galvanized clothesline, strung around the outside of the area to be protected and carried on poles 20 feet above the ground. No. 608 service insulators, screwed into either side of the poles, supported the cables. On one cable, 3-inch porcelain tube insulators, spaced 10 feet apart, were threaded prior to attaching the cable to the post insulators. The second cable was pulled in and wired to the 3-inch tube insulators. This tightened the perch wires and spaced them one-half inch apart (see Figure 1). A neon sign transformer (12,000 volts, 30 milliampere rating) was fastened to one of the poles and the high voltage terminals wired to the bird perch wires. The primary circuit leading from a 110-volt outlet was wired to the primary terminals of the transformer.

2) The primary circuit, including main switch and fuse-box, time clock and electric-light sockets, is shown in Figure 2. The electric light, or lights, reduced the voltage to the transformer. A high wattage light allows more current to the transformer than one with a lower wattage. The current to the transformer was adjusted by varying the wattage of the lights so that the perch wires were operated at a voltage high enough to shock the birds and yet not high enough to arc continually and burn out. With the apparatus described, a 100-watt light proved satisfactory under all weather conditions.

Prior to starting the modified device, a flock of more than 500 goldfinches was feeding on lettuce seed plots. The apparatus was started at 4 p.m. and the birds that alighted on the perch were positively but not fatally shocked. The birds continued to feed in the plot area until sundown. The following day, only about 25 birds returned to the plot area. These birds continued to feed in the plot area until they migrated.

Originally the birds were quite tame and it was difficult to make them leave the area; they ran along the lettuce rows and hid between the plants. Once the electric perch was put in operation, the small remaining flock became wild and, when approached, immediately left the area and hid in nearby trees. On returning to feed, they swooped in low or flew high and came in without using the perch wires.

The main difference between the modified bird perch and the original apparatus is the positive shocking of the birds through their feet. This was due to the fact that even small birds contacted both wires when alighting.

Our experience indicates that the electric bird perch should be started well in advance of seed ripening and before birds form the habit of feeding in the area. Our investigations confirm other experiments (2) that, once the pattern of feeding becomes established, it is difficult, if not impossible, to break it.

An alternate feeding area should be provided, reasonably close to the protected area. The value of supplying a feeding area for the birds was demonstrated during the period when the winter oats were protected. At this time, a winter oat nursery suffered heavy bird damage while the nearby oat crop, in the protected area, was unmolested. No alternate feeding area was provided with the lettuce crop.

The protected area should be located in the open, away from large trees and high wires, so that there are no alternate places for birds to perch.

REFERENCE

1. Pfeifer, R. P. A bird-control apparatus for experimental plots. Agron. J. 48 : 139-141. 1956.
2. The duck problem. Can. Wildlife Service, Dept. Northern Affairs & Nat. Resources, Ottawa.

—R. H. TURLEY,
Canada Department of Agriculture,
Experimental Farms Service,
Saanichton, B.C.

March 26, 1958

NOTE ON A PORTABLE FIELD GROWTH CHAMBER FOR WINTER INJURY STUDIES

Many investigators have speculated on the effect of drying winds, ice sheets, snow cover, cold temperature, alternate freezing and thawing, etc., on wintering crops. Survival of crops under these conditions is usually evaluated in the spring. Therefore, estimates of the time and cause of injury are mainly matters of conjecture. A device that would enable wintering crops to "revive" and grow at any time during the winter was therefore conceived. The winter damage up to the point of "revival" could be determined by comparing the revived growth with the growth of the previous fall. This device consisted of a bottomless, insulated (2" fiberglass) aluminum chamber (approximately a 5-foot cube) that was equipped with electrical heaters and fluorescent lights.

Figure 1 shows the main design and construction details of the chamber and Figure 2 shows the chamber in the field. All controls and ballasts were mounted in a cabinet on the outside of the chamber proper (not shown). The light panel was suspended on counter-weights and pulleys, so that it could be raised or lowered to the desired level. With white light, and instant start tubes, an illumination of 1400-foot candles was achieved at 18 inches, and 1200-foot candles at 30 inches. Six strands of soil heating cable (total 800 watts) were mounted around the bottom edge of the chamber wall and were controlled at 75° F. from a thermostat element placed on the soil surface adjacent to the inside wall. Eight heating straps (500 watts each, not shown) were located in the air intake duct and were controlled by a thermostat, set at 70° F., which was located at the exit of the intake duct. The three air dampers were controlled simultaneously by a single modutrol motor which was actuated by a thermostat mounted 12 inches from the chamber ceiling. When the intake and outlet

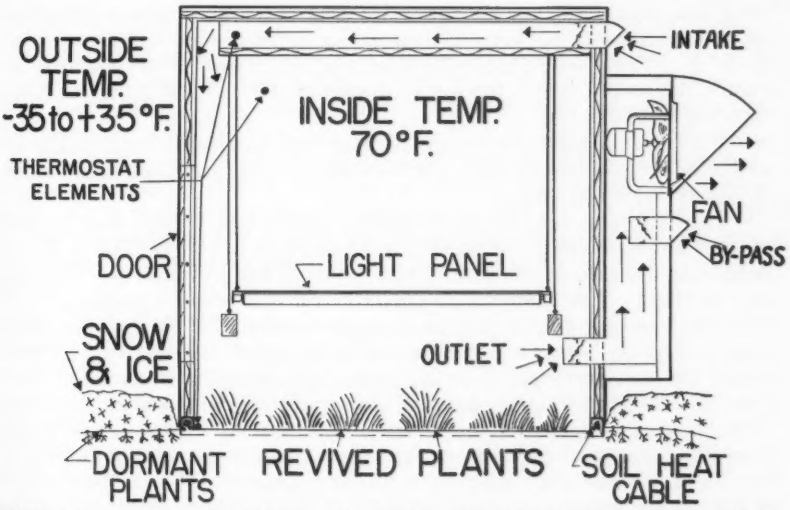

FIGURE 1.—Diagram of portable growth chamber showing important construction details.

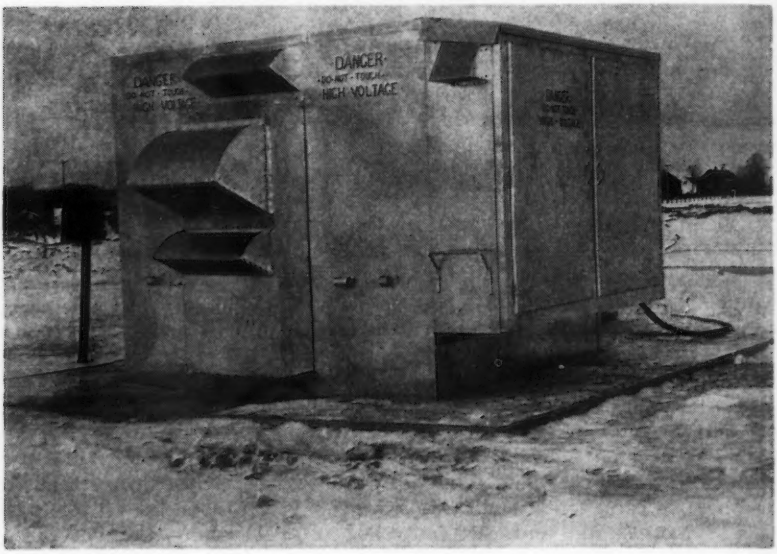

FIGURE 2.—Portable field growth chamber in place on a plot that had been covered with 4 inches of ice.

dampers opened, the by-pass damper closed and vice versa. This permitted the use of a constant speed fan, and air could circulate through the by-pass port and fan, when the intake and outlet ports were closed. The air damper thermostat was set to completely close the dampers below 70° F. and completely open them above 80°F. Auxiliary heat was supplied by two portable heater fans (1320 watts each) thermostatically controlled at 70° F. They were suspended near the wall, just above the vegetation. Maximum power load was approximately 11,000 watts and was supplied at 110 volts.*

This Note presents the results of tests that were conducted during the winter of 1956-57 to determine the feasibility of this approach to the study of winter injury to crops.

In the fall, a network of 20 thermocouples was buried under a plot of alfalfa (artificially covered with a 4″ sheet of ice on December 20) to determine the rate of advance of heat through the soil after the chamber was in place. The chamber was placed over this area on January 5 and the inside temperature was held at approximately 70° F. and the lights were turned on between 6 a.m. and 6 p.m. (panel lowered to 30 inches above the soil surface). The ice cover was completely melted 2 days after placement of the chamber and the remaining water was pumped out. The warming influence of the chamber is shown in Figure 3. Although frost had penetrated 24 inches under the ice, the temperature at this depth was 34° F., 7 days after placement of the chamber. The resultant effect of the chamber was a warmed "pocket" of soil in which plants may grow

* This unit was designed and built by J. W. White, Engineer, and W. Kalbfleisch, Principal Engineer, of the Field Husbandry, Soils and Agricultural Engineering Division, Experimental Farms Service.

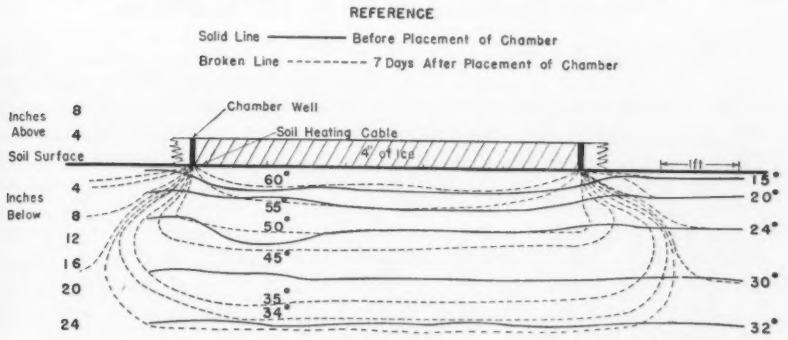

FIGURE 3.—Soil temperature (°F.) profile before and 7 days after placement of winter survival chamber.

with very little border effect. The mean air temperature for the period of this test was 13° F. (The minimum temperature one night was −37° F.).

Although the fan in the chamber provided for 1000 cu. ft. per minute ventilation (with intake dampers full open), no excessive drying of the soil took place. Coleman moisture blocks placed at 4-inch depth in the soil indicated moisture levels near field capacity after 20 days. No moisture condensation was apparent on the inner walls of the chamber at any time. The aluminum skin of the chamber served as a vapour barrier because it was sealed with asphalt paint at each joint.

With the same control settings as above, the portable growth chamber was placed on various alfalfa plots on January 5, February 2, February 24, and March 13, to test the effectiveness of the chamber in reviving the crop. The most rapid revival of alfalfa occurred in 8 days and the longest time for revival was 18 days. In each case the crop grew well and was disease-free.

The criterion of growth used in each of the tests of this series was development of crown cover. It will be necessary, however, to establish additional standards by which revived growth could be fully compared to the growth of the previous fall. Rate of growth, crop yields a certain number of days after revival, plant colour, general vigour, disease, root conditions, etc., would have to be considered in addition to crown cover.

The results of this series of experiments have shown the feasibility of this approach to the investigation of many winter injury problems. With adjustments in dimensions, a chamber of this type could be used for many kinds of wintering plants, shrubs, small trees, etc.

—R. M. HOLMES, Agronomist,
Field Husbandry, Soils and Agricultural
Engineering Division,
Experimental Farms Service,
Canada Department of Agriculture,
Ottawa, Ontario
—G. W. ROBERTSON, Meteorologist,
Department of Transport; seconded to the
Field Husbandry, Soils and Agricultural
Engineering Division, Experimental Farms Service.

NOTE ON DIFFERENCES IN SUSCEPTIBILITY TO SCLEROTINIA WILT IN SUNFLOWERS

The fungus *Sclerotinia sclerotiorum* (Lib.) De Bary causes a wilt in sunflowers (*Helianthus annuus* L.). It is soil-borne and has a wide host range. Infection appears in sunflower fields in the late bud or bloom stage and spreads during the remainder of the growing season. The attack is usually at the base of the plant but may occur in any portion of the stem and the receptacle. The effects of an attack at the base or in the stem are sudden and dramatic. Plants wilt, die and may break over. The main diagnostic features are pale brown or almost white colour of the rotted areas and large, black, irregular-shaped sclerotia in the dead parts. Most sunflower fields in Manitoba have shown only a trace of the disease, but in a few instances 50 per cent or more of the plants have been destroyed. Crop rotation is at present the only means of control.

In 1953, 44 varieties and inbred lines of sunflowers were planted in three replicates, using single-row plots 20 feet long. The test field had grown sunflowers each season since 1949. The mean infections by *Sclerotinia*, expressed as percentage transformed to $\sin^2\theta$, ranged from 27.2 to 71.6. The 10 entries with lowest infection and the 10 with highest infection were replanted in the same area in each of the years 1954 to 1956, using three replicates and the same plot size. Table 1 gives the mean value for each season, the 4-year average and the rank for each of the 20 entries. The average number of plants per plot was 15 in 1955 and 30, 31 and 33 in the other 3 years. The infections were almost entirely in the basal portions of the plants.

TABLE 1.—MEAN PERCENTAGE NATURAL INFECTION BY *Sclerotinia sclerotiorum* EXPRESSED AS DEGREES $\sin^2\theta$ AND RANK (IN BRACKETS) OF MENNONITE VARIETY AND 19 INBRED LINES OF SUNFLOWERS AT ALTONA, MANITOBA

Line	1953	1954	1955	1956	4-year average
CM 10	30.1 (2)	11.9 (1)	8.3 (2)	21.4 (5)	17.9 (1)
CM 11	32.6 (5)	15.8 (2)	16.7 (5)	19.4 (4)	21.1 (2)
CM 3	27.2 (1)	38.8 (8)	17.6 (6)	12.3 (1)	24.0 (3)
CM 14	34.2 (6)	39.4 (9)	0.0 (1)	34.7 (13)	27.1 (4)
CM 16	35.4 (8)	41.9 (13)	24.8 (9)	13.0 (2)	28.8 (5)
CM 17	32.4 (3)	33.3 (6)	19.9 (7)	37.2 (15)	30.7 (6)
CM 18	32.3 (4)	28.6 (4)	37.6 (15)	27.8 (9)	31.6 (7)
CM 19	37.7 (10)	26.4 (3)	38.7 (18)	33.1 (10)	34.0 (8)
S-37-388	62.9 (12)	36.7 (7)	15.7 (4)	21.8 (6)	34.3 (9)
CM 20	34.4 (7)	41.7 (12)	10.0 (3)	54.6 (20)	35.2 (10)
CM 21	68.4 (16)	28.9 (5)	22.2 (8)	33.5 (11)	38.3 (11)
CM 22	35.8 (9)	44.7 (14)	40.0 (19)	34.9 (14)	38.9 (12)
CM 23	62.4 (11)	39.5 (10)	31.4 (11)	26.4 (8)	39.9 (13)
CM 24	66.5 (14)	61.2 (20)	36.5 (14)	17.7 (3)	45.5 (14)
CM 25	64.4 (13)	41.2 (11)	37.7 (16)	39.8 (17)	45.8 (15)
CM 26	67.9 (15)	50.8 (18)	25.4 (10)	39.5 (16)	45.9 (16)
Mennonite	71.6 (20)	47.3 (16)	37.9 (17)	33.8 (12)	47.6 (17)
CM 12	68.7 (17)	48.6 (17)	32.6 (12)	52.2 (18)	50.5 (18)
CM 13	70.7 (18)	46.1 (15)	63.5 (20)	24.7 (7)	51.2 (19)
CM 15	71.4 (19)	58.8 (19)	34.9 (13)	52.7 (19)	54.0 (20)
L.S.D. (P=.01)	30.4	22.1	13.3	25.2	14.8

The 4-year average ratings varied from 17.9 to 54.0 (Table 1). Significant differences at the 1 per cent level of probability existed between the means of the inbreds in each year and also between their 4-year averages. The line CM10 had the lowest infection, ranging in rating from 8.3 to 30.1 over the four seasons. It was followed closely by CM 11 with a range of 16.7 to 32.6. In contrast, other entries, including the Mennonite variety and lines CM 15, CM 22 and CM 25, had greater infection in all seasons than any shown by CM 10 and CM 11.

There were marked inconsistencies in the infection of various lines from year to year. This was indicated by a highly significant inbreds × years interaction in the analysis of the 4-year data. Most noticeable in this regard was line CM 14, which had no infection in 1955 and ratings of 34.2 and higher in each of the other years. Other lines with similar behaviour were CM 20 and CM 24, with ranges of 10.0 to 54.6 and 17.7 to 66.5 respectively.

Examination of the rank data in Table 1 shows that 9 of the 10 lines with lowest infection, as judged by the 4-year averages, were among the 10 lines originally selected for low infection on the basis of the 1953 data only. The exception was the line S-37-388, which had unusually high infection in 1953, as judged by its rating in the succeeding three seasons. Further, the 10 lines selected for low infection in 1953 occupied 20 of the 30 positions among ranks 1 to 10 for the 3 years, 1954 to 1956. Table 1 shows line CM 10 ranked first or second in 3 years, as contrasted with CM 15 in position 19 for three seasons.

The results are not sufficiently consistent to be thoroughly conclusive but they do indicate that differences in susceptibility of varieties or lines to Sclerotinia wilt exist in sunflowers. Assuming that these differences are inherited, it should be possible, over an extended period, to develop varieties with either low susceptibility or even resistance to the disease and thus open another avenue, besides crop rotation, for its control. In that the pathogen has a wide host range this possibility is of special interest. Further investigations into the various aspects, especially the inheritance, are planned.

—Eric D. Putt,
Forage Crops Division,
Experimental Farms Service,
Canada Department of Agriculture,
Morden, Manitoba.

June 3, 1958

NOTE ON PERSONAL ERROR IN ESTIMATES OF BASAL AREA WHEN USING THE VERTICAL POINT METHOD[1]

Although the vertical point method of vegetation analysis is in wide use, few investigators have studied the degree of personal error inherent in the method. Goodall (2) found significant differences between observers in their estimates of percentage cover in three of six species studied. Ellison (1) found variations in estimates of percentage cover of *Bouteloua dactyloides* on one of three sites ranging from 68 to 87 per cent, depending on the observer.

Percentage basal area data obtained using the vertical point method on a variety of range and pasture types in southern Alberta were available for study. These data were based on an examination of 12,000 or more points per sampling site and were obtained by two individuals, designated A and B, both experienced in the use of the point method. This intensity of sampling was considered to be sufficient to yield accurate information about even minor constituents of the sward. The percentage data were subjected to angular transformation and were analysed using the paired plot technique. The results obtained are shown in Table 1.

The data show that some differences between observers in their estimates of basal area were encountered. The difference in estimates of basal area of *Agropyron smithii* between observers was significant (P = 0.05). A significant difference (P = 0.01) in estimates of basal area of *Bouteloua gracilis* between observers was indicated on one of two sites. The significant difference (P = 0.01) between observers shown for *Stipa comata* at three sites is of interest since the data for each site were obtained at widely separated locations over a 2-year period. These data suggest that particular care should be taken when estimating basal area on sites dominated by this species and that frequent checks between individuals

TABLE 1.—PERCENTAGE BASAL AREA OF GRASS SPECIES AS ESTIMATED BY TWO OBSERVERS USING THE VERTICAL POINT METHOD AT VARIOUS SITES

Species	Estimates of basal area by observers		
	Site	A	B
Agropyron cristatum	1	4.3	4.6
	2	5.5	6.0
Agropyron smithii		5.4*	4.4
Bouteloua gracilis	1	28.6	36.5**
	2	18.4	20.7
Danthonia parryi		12.2	10.8
Festuca idahoensis		0.1	0.1
Festuca scabrella		3.6	2.5
Stipa comata	1	0.6	2.2**
	2	1.1**	0.4
	3	2.2**	1.1

* Significant difference between observers (P = 0.05)
** Significant difference between observers (P = 0.01)
[1] Contribution from the Forage Crops Division, Experimental Farms Service, Canada Department of Agriculture.

would be helpful in maintaining accuracy. Good agreement between observers was shown for *Danthonia parryi*, *Festuca idahoensis*, *Festuca scabrella*, and a cultivated species, *Agropyron cristatum*. The data do not indicate any tendency toward either over-estimation or under-estimation of basal area on the part of individual observers.

While it is not possible, in this limited discussion, to examine the magnitude of personal error encountered in studies with other methods of vegetation analysis, it may be said that the personal error inherent in the vertical point method appears to be less than that noted for these other methods. In this study, observers did not examine the same pins. A further study is planned which will involve successive observations of the same pins by different observers.

REFERENCES

1. Ellison, L. A comparison of methods of quadrating short-grass vegetation. J. Agr. Research 64:595-614. 1942.
2. Goodall, D. W. Some considerations in the use of point quadrats for the analysis of vegetation. Australian J. of Sci. Research, Series B, Biological Sciences, 5:1-42. 1952.

—A. JOHNSTON,
Forage Crops Section,
Experimental Farm,
Lethbridge, Alberta.

February 27, 1958

NOTE ON ALTERATION OF CREEPING HABIT OF BROMEGRASS BY REJUVENATION[1]

It is common in bromegrass seed areas of Western Canada to rejuvenate seed fields by periodic tillage. Ploughing is the most common method of rejuvenation as it gives more lasting improvement in seed yields than lighter forms of cultivation. Following spring ploughing the sod is worked down and seeded to oats so as to provide a modest return the year of rejuvenation. Seed crops are taken for 3 to 5 years and then rejuvenation treatments are repeated. Improvement in seed yields following ploughing is frequently greater than that obtained from nitrogen fertilizers.

Two tests at Saskatoon show that ploughing may increase the frequency of creeping types of bromegrass. The first of these trials concerned the Parkland variety which was bred for the restricted creeping habit. The foundation seed plot of this variety was ploughed in the fall of 1949, and seed harvested in 1951. This seed was used to establish a row of 45 plants, spaced 3 feet apart in 1952. Adjacent rows of 45 spaced plants represented non-rejuvenated Parkland, registered Parkland from an Alberta seed grower, and a northern commercial lot from a local seed-house. The average degree of creep noted in 1955 is shown in Table 1.

TABLE 1.—SPREAD IN INCHES OF BROMEGRASS PLANTED 1952 AND MEASURED 1955

Strain and source	Average creep, inches
Parkland 1948, unrejuvenated foundation	20.72 ± 0.74
Parkland 1951, rejuvenated foundation	25.25 ± 0.78
Parkland 1951, registered	20.85 ± 0.78
Commercial 1951, local seed company	31.54 ± 1.32

Rejuvenation by ploughing significantly increased the creeping habit of Parkland. This variety shows some variability in creeping habit and presumably plants with more strongly creeping tendencies predominated following thinning by ploughing. The registered seed lot showed retention of the original habit of Parkland to a gratifying degree.

The second test involved a stand of northern commercial bromegrass established in 1949. In 1953, the stand was becoming "sod-bound" and four plots were rejuvenated by ploughing. Seed collected from these plots in 1956 was used to establish a spaced-plant nursery in comparison with plants grown from seed of four non-rejuvenated check plots. Four paired rows, each of 22 plants, were used to compare the rejuvenated and unrejuvenated stocks. The average creep of rejuvenated stock plants, one year after planting, was 25.54 ± 0.70 inches. This was significantly greater than the average creep of 23.24 ± 0.56 inches noted for the non-rejuvenated stock.

[1] Contribution No. 4, Canada Department of Agriculture Research Laboratory, Saskatoon, Sask.

Evidence that cross-pollinated species may be modified rapidly by climatic and management pressures continues to accumulate. It is apparent that drastic tillage practices, such as ploughing, can markedly influence the nature of strains and should not be permitted in the propagation of new varieties. No data were obtained on the effects of rejuvenation on seed and forage yields. However, the unfavourable forage yields of commercial bromegrass in relation to those of recent bred strains may result from progressive deterioration of the northern type by continuous cycles of ploughing.

—R. P. KNOWLES,
Research Officer,
Forage Crops Section,
Canada Agriculture Research Laboratory,
University Sub-Post Office,
Saskatoon, Saskatchewan.

June 2, 1958